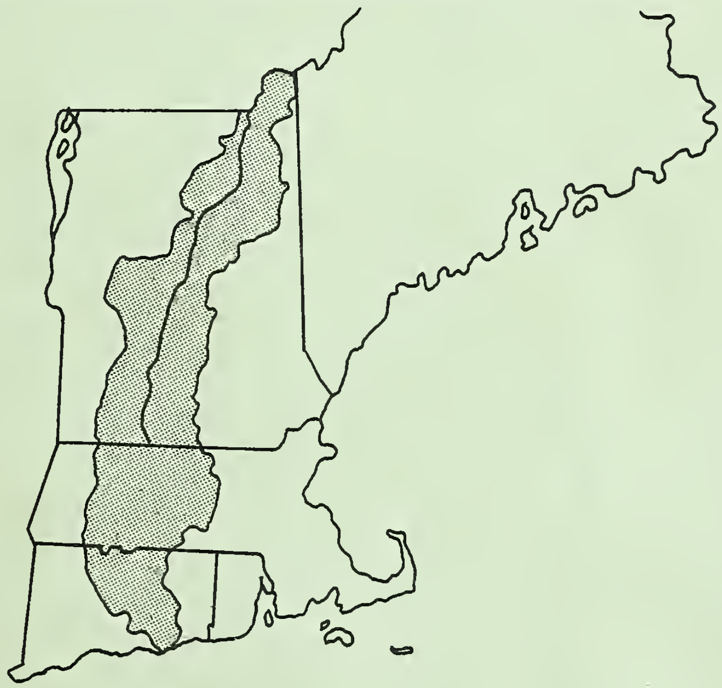
SURVEY REPORT

CONNECTICUT River Watershed

VERMONT, NEW HAMPSHIRE, MASSACHUSETTS, CONNECTICUT



PROGRAM FOR RUNOFF AND WATERFLOW RETARDATION
AND SOIL EROSION PREVENTION

U.S. DEPARTMENT OF AGRICULTURE

1951

UNITED STATES DEPARTMENT OF AGRICULTURE

SURVEY REPORT

ON PROGRAM OF RUNOFF AND WATER FLOW RETARDATION

AND SOIL EROSION PREVENTION

CONNECTICUT RIVER WATERSHED

Vermont, New Hampshire, Massachusetts, Connecticut

Pursuant to the Act of June 22, 1936 (49 Stat. 1570),
as amended and supplemented.

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INTRODUCTION

AUTHORITY

This report is submitted under the provisions of the Act of June 22, 1936, (49 Stat. 1570), as amended and supplemented.

PURPOSE AND SCOPE

The report presents the results of a survey which has been made of the Connecticut River watershed and outlines a program of land use and management developed to alleviate flood and sediment problems. The program consists of interrelated measures and practices to control runoff, retard water flow, and prevent soil erosion on all of the watershed except the 115 square miles in Canada. The report presents recommendations for the installation and maintenance of the program, together with an analysis of its costs and benefits.

The Connecticut River drains an area of about 11,260 square miles, (7,206,400 acres) of which 11,145 square miles (99 percent) are in the States of Vermont, New Hampshire, Massachusetts, and Connecticut; and the remainder is in Canada. All conditions that contribute to flood and sediment damage were investigated.

RECOMMENDATIONS

It is recommended that a program of runoff and water flow retardation and soil erosion prevention be installed during a 20-year period in the Connecticut River watershed. Objectives of the recommended program are to reduce floodwater and sediment damage and to conserve soil and water resources.

These objectives will be accomplished through the installation and maintenance of the following interdependent measures and practices: (1) improved woodland-management practices on 4,354,350 acres of forest land; (2) conversions in land use in accordance with land capability; (3) improved management of 1,465,000 acres of open agricultural land, including pasture improvement and management, crop rotation, gully stabilization, installation of farm waterways, and contour strip cropping; (4) channel improvement and stream-bank stabilization; (5) other soil and water conservation measures and practices to complete a basic system of soil and water conservation in accordance with the needs and capabilities of the land of the watershed; and (6) educational assistance, direct aids and technical service to landowners to inform them of the program, to assist in the application of practices and measures and to ensure that they are applied in proper combination to meet the objectives of the program.

The cost of installing the recommended program during a 20-year period is estimated to be $31,471,000. The Federal Government will contribute about $17,563,000 and local interests will spend $13,908,000 or its equivalent.1/

Maintenance will be required to protect investments and assure continued benefits. The estimated cost of annual maintenance is $2,238,000. The Federal Government will spend about $281,000 and local interests about $1,957,000.

The program herein recommended includes the intensification, acceleration, and adaptation of certain activities under current programs of the Department of Agriculture, and additional measures not now regularly carried out in such programs, all of which are necessary to complete a balanced runoff and water-flow retardation and erosion control program for the watershed. It is recommended that the Secretary of Agriculture be authorized to carry out this program. The extent to which the work recommended in this program is to be carried out under other authorities will be considered by the Secretary in requesting appropriations for the conduct of the recommended program. Although the current activities of the Department primarily related to the Flood Control Act are not

1/ Labor, material, equipment, land easements, right of ways, and other contributions in lieu of cash payments.

included in the program herein specifically recommended, this program is based on the continuation of such current activities at least at their present level. The extent to which the measures in the recommended program may be carried out by an increase in the current programs of the Department will be taken into account in requests for the appropriation of funds to carry out the recommended program.

The recommended measures will be installed on non-Federal land under cooperative arrangements with state and local governments, soil conservation districts, or other agencies acceptable to the Secretary of Agriculture.

The Secretary of Agriculture may make such modifications or substitutions of the measures described herein as may be deemed advisable due to changed physical or economic conditions or improved techniques whenever he determines that such action will be in furtherence of the objectives of the recommended program.

The Secretary of Agriculture may construct such buildings and other improvements as are needed to carry out the measures included in the recommended program.

The authority of the Secretary of Agriculture to prosecute the recommended program shall be supplemental to

all other authority vested in him, and nothing in this report shall be construed to limit the exercise of powers heretofore or hereafter conferred on him by law to carry out any of the measures described herein or any other measures that are similar or related to the measures described herein.

Attainment of the benefits estimated in this report depends on the installation and proper maintenance of all phases of the recommended program. The average annual benefit from the installation and maintenance of the recommended program is estimated at $16,675,200.

The ratio of the estimated average annual benefit to the average annual cost of the recommended program is 3.2 to 1.

DESCRIPTION AND ECONOMY OF THE WATERSHED

LOCATION AND SIZE

The Connecticut River watershed, extending south from the Canadian boundary through western New England to Long Island Sound, is the largest drainage area in New England (fig. 1). It is about 280 miles long with a maximum width of 62 miles. The total area is 11,260 square miles: 115 in Canada; 3,911 in Vermont; 3,096 in New Hampshire; 2,712 in Massachusetts; and 1,426 in Connecticut.

PHYSIOGRAPHY AND DRAINAGE

The watershed includes the rugged ridges of the Green and White Mountains, with their narrow, steep valleys and high mountain peaks as well as the more gently rolling topography of the Berkshires and the minor ridges of central Connecticut and Massachusettes. Elevations range from sea level to more than 5,000 feet.

The main river flows down a long, narrow valley, falling approximately 1,640 feet between First Connecticut Lake and tidewater at Hartford, Connecticut. Nearly two-thirds of this fall occurs in the upper one-third of the watershed. Numerous tributaries rise in the mountainous country surrounding the main valley. The principal tributaries, characterized by steep gradients in their upper reaches, are the Nulhegan, Passumpsic, Wells, Waits, Ompompanoosuc, White, Ottauquechee, Black, Williams, and the West in Vermont; the Upper Ammonoosuc, Mascoma, Sugar, and Ashuelot in New Hampshire; the Millers, Deerfield, Chicopee, and Westfield in Massachusetts; and the Scantic, Farmington, Hockanum, and Salmon in Connecticut. The drainage areas of these tributaries range from about 100 square miles to 725 square miles.

GEOLOGY AND SOIL

Glaciation occurred over the entire watershed. Mountain tops were scoured and glacial drift was deposited in the valleys and on the lower slopes. The net effect was a diminishing of the relative relief and the development of progressively deeper soils at lower elevations. The deposits left by the retreating glaciers consist mainly of outwash, terminal moraine, and glacial lake deposits. This is particularly true in the lower half of the watershed.

Underlying rock masses are largely intrusive granites, schists, and gneisses of igneous and metamorphic origin. These rocks are essentially hard, impermeable, and insoluable, except where weathered and fractured near the surface.

In the northern part of the watershed, and in the eastern and western highlands of the southern portion, the soils are derived from glacial till deposits. This mantle of glacial material varies in thickness. On the higher ridges and upper mountain slopes it is made up of a relatively shallow, sandy loam, characterized by numerous rock outcrops. This soil type becomes progressively deeper at lower elevations, reaching maximum depths of 30 and 40 feet in the valley bottoms. On the other hand, in the central lowlands of the southern half of the watershed the soil mantle is generally deep, with many deposits of glacial outwash.

Soils formed from Triassic sandstone and shale by moderate glacial action occur over a considerable area in Massachusetts and Connecticut. These soils have a characteristic reddish color and are highly regarded for cropping purposes. They are easily eroded. The most serious gully development and loss of potential cropland in the valley area has occurred in these red soils. The balance of the valley soils are either glacial outwash or alluvial in origin. Nearly all are sandy. This textural condition makes possible easy cultivation and intensive use for potato, tobacco, and vegetable production. Where the soil is not protected by vegetation, erosion by wind--both in winter and summer--is severe. Much of the land composed of these outwash and alluvial soils is nearly level. However, runoff and erosion from such lands when intensively cultivated are serious.

CLIMATE

Average annual precipitation (rainfall plus snowfall converted to water) is about 42 inches. Maximum precipitation (about 48 inches) occurs along the coast and in the mountain area; minimum precipitation (about 35 inches) occurs in the central portion of the valley. Precipitation is well distributed throughout the year. The average annual snowfall is 64 inches, ranging from a mean of 82 inches in the north to 46 inches in the south. Snow can be expected from October

to May. Temperatures range from a high of 106° F. to a low of -50° F. Killing frosts may occur as early as September and as late as May. In areas of open cropland, understocked and poorly managed forests, and overgrazed pasture, much of the ground remains frozen throughout the winter.

HISTORY OF SETTLEMENT AND INDUSTRY

Early settlements, confined to the tidal portion of the river, were established between 1635 and 1640. Most of the good bottom land was cleared by 1700, after which colonists began the extensive clearing of upland areas. This continued until about 1800 and resulted in converting about half of the watershed area to agricultural use. Farming was diversified and small self-sufficient family units were the rule.

The Revolutionary War and subsequent efforts to break commercial ties with England gave impetus to small-scale industry; factories for the manufacture of textiles, metals, and a wide variety of other products were firmly established in many small towns by 1840. This industrial development provided a growing market for agricultural products as well as employment for members of rural families.

Major changes occurred in the agricultural and industrial economies during the 19th century. The development

of the railroads, opening up the western part of the United States, expanded the industrial market and permitted the introduction of low-cost western agricultural products. Manufacturing concentrated in cities, which entered a period of rapid growth, particularly in Massachusetts and Connecticut. Farming declined and many upland farms become submarginal and were abandoned. These areas gradually reverted to woodland.

Lumbering was always an important factor in the economy of the area. Early operations--consisting of removal of high-volume, high-value trees--were more or less selective and did not seriously change woodland hydrologic conditions. About 1850, however, the increased demand for lumber for urban construction, followed by the development of the circular saw and the establishment of the pulp and paper industry, resulted in accelerated logging and changes in cutting practices. Clear-cutting of all merchantable timber became the rule. The period of maximum lumber production occurred between 1890 and 1910. During this period practically all of the virgin timber and substantial volumes of second-growth timber were removed. Forest fires often followed logging and large areas were denuded and left in a condition favoring rapid runoff and erosion.

Industry has continued to expand during the 20th century. Agricultural activity has declined and the extensive general farming, which characterized the earlier period, has given way to specialized dairy, truck, and tobacco farming.

POPULATION

Approximately one and a quarter million people lived in the watershed in 1940. About 69 percent lived in cities, 22 percent were rural nonfarm residents, and 9 percent lived on farms. Most of the large industrial cities are in Massachusetts and Connecticut. These two States account for more than 75 percent of the total population.

TRANSPORTATION SYSTEM

An extensive transportation system including railroads, highways, airlines, and waterways serves the watershed. Many of the railroads and highways are located in the flood plain of the river and its tributaries. They are subject to serious flood and sediment damage. In some places fills and bridges encroaching on stream channels restrict flood flows and cause widespread damages. Railroad and highway fills and cuts are also prime sources of sediment

WATER SUPPLIES AND HYDROELECTRIC DEVELOPMENT

Surface water is the major source of supply for domestic use. Numerous small subwatersheds have been developed, by municipalities or private companies, for the production of domestic water. The Metropolitan Water District of Boston has constructed a diversion dam on the Ware River to direct flood waters to the Quabin Reservoir. In some places, particularly in Massachusetts and Connecticut, domestic water-supply reservoirs and drainage areas have been closed to all other uses.

Large quantities of water are used by manufacturing plants in the watershed. The paper industry in the central valley, the textile and leather mills, and other processing plants scattered over the watershed require millions of gallons of pure, clean water daily. Pollution from industrial waste and domestic sewage is a problem in the watershed. It is particularly serious during periods of low flow and increases treatment costs at all times.

Hydroelectric power plants are of considerable importance. The total installed capacity in 255 plants is about 680,000 horsepower. Many of these plants are operated to produce power for the industries that own them. About 59 plants are operated to produce power for sale. Most of the power is produced in "run-of-the-river" plants. Only about

431,000 acre-feet of storage capacity is available in existing power reservoirs. Floods and low flows seriously affect power production.

LAND OWNERSHIP AND USE

In 1948, approximately 91 percent (6,515,500 acres) of the watershed was privately owned; the remaining 9 percent (619,500 acres) was in public ownership. Farmers owned 3,387,000 acres, other private owners 3,128,500 acres. It is estimated that there are approximately 31,000 farm owners. Other private land, exclusive of that in urban and suburban areas, is held by about 20,000 owners. Public ownership, principally forested land, consists of 294,000 acres of national forest and 325,500 acres of state and municipal land.

Sixty-seven percent (4,780,000 acres) of the total area is in forest or brush cover. Open agricultural land occupies about 23 percent (1,670,000 acres); urban areas, water areas, and roads cover about 10 percent (685,000 acres). Nearly one-half (759,000 acres) of the open agricultural land is used for the production of clean-tilled crops and rotation hay; about 110,000 acres are used for permanent hay; about 675,000 acres are in pasture; the remainder, 126,000 acres, is either idle or used for miscellaneous purposes.

FLOOD PROBLEMS

FLOOD OCCURRENCE

Floods have become a serious threat to the people who live in the flood plains of the Connecticut River and its tributaries. During the period from 1840 to 1950, 29 major floods were recorded at Hartford--an average of one every 3.8 years. In the 200 years of record preceding 1840, only 18 major floods were recorded--an average of one every 11.6 years. Local floods, affecting one or more tributaries, have occurred even more frequently than the basin-wide floods.

The floods result either from rainfall or from rainfall accompanied by snow melt. Runoff from snow melt is important in producing floods during the winter and early spring months. Storms moving over the watershed in those seasons produce heavy precipitation and are very effective in melting the snow. This often creates critical flood conditions. Short, intensive rainstorms occur frequently during the summer months and are responsible for most of the local flash floods.

LAND FACTORS AFFECTING FLOODS

Continued and widespread misuse of land over a long period of years has seriously upset soil and water relationships

in the watershed. More than two-thirds of the present forest cover lacks effectiveness in retarding runoff and preventing erosion. About three-fourths of the open land in farms contribute significantly to flood and sedimentation problems. Of the open land that contributes to the flood problem, 52 percent is cropland and hay land, 37 percent is pasture, and 11 percent is classed as idle or miscellaneous.

The condition of the forest cover is an index of the effectiveness of woodland areas for watershed protection. The stands generally are poor as a result of past mismanagement. Clear cutting, improper logging practices, repeated fires, and livestock grazing have created understocked stands often composed of temporary species. Under such conditions the forest floor---the key to good hydrologic conditions---is poorly developed and surface infiltration rates and soil-moisture storage capacities are reduced. Poor forest cover may permit an impermeable frost layer to form during the winter months.

Many access and skid roads, left from previous timber-harvesting operations, are sources of erosion and sedimentation. They also provide channels for the rapid runoff of water that normally would infiltrate and percolate into forest soils.

Of the area in farm woodlands about one-half (807,000 acres) is grazed by domestic livestock. This grazing destroys the litter and humus and compacts the soil, reducing infiltration and storage capacity. It prevents establishment of reproduction, reduces stand vigor, and results in deteriorated forest and soil conditions.

Intensive cultivation, tillage without regard to direction of slope, and failure to maintain organic content of the soil have led to rapid runoff and serious erosion on much of the cropland. Many pastures are overgrazed and due to lack of vegetative cover, resulting soil conditions are inadequate to permit infiltration of rainfall at the maximum attainable rate. Soil compaction, which reduces infiltration and percolation rates as well as storage capacity, is also common on overgrazed pastures.

Present land practices have accelerated stream-bank erosion. Many stream banks have been cleared of protective cover. This, coupled with increased flood flows, concentrations of stock along streams, and plowing to the bank, has caused severe erosion and loss of land. Stream channels have become clogged with debris, rocks, and sediment. Stream behavior has been seriously affected in the mountainous headwaters as well as in the lower reaches.

FLOOD AND SEDIMENTATION DAMAGES

Heavy losses result from both basin-wide and local floods. Industrialized urban centers and transportation systems suffer the greatest losses. Although spectacular major floods cause heavy damages, local flash floods, because of their greater frequency, cause more than half of the average annual damage. The September 1938 flood, which is typical of the major basin-wide floods, forced 12,000 families out of their homes, flooded out about 1,500 commercial and industrial concerns, damaged or washed out some 600 highway and railroad bridges, and inundated about 25,000 acres of cropland. Local flash floods are exemplified by the February 1929 freshet on the Mattabesset River in Connecticut. This freshet caused heavy flood damage to 150 homes in New Britain and created a serious direct unemployment problem by forcing two large factories to close down.

Estimated average annual flood and sedimentation damage totals $6,285,700 (table 1).

AGRICULTURE

Agricultural losses are as widespread as the distribution of the alluvial soils--from the rich tobacco lands in

Table 1.--Summary of average annual flood and sedimentation damage[1]

Type of damage	Average annual loss
Direct damage by--	
Floodwater:	
Agricultural	$ 424,000
Industrial[2]	907,700
Urban[3]	733,600
Transportation	1,249,300
Sedimentation[4]	113,200
All direct damage	3,427,800
Indirect damage	2,857,900
Total[5]	$ 6,285,700

1/ Computed on the basis of 1949 costs.

2/ Includes damages to industries and utilities.

3/ Includes damages to commercial, residential, and public properties.

4/ Includes damages to highways and reservoirs, and stream-bank erosion.

5/ Of this amount approximately $3,010,000 of damage will be prevented by structures now installed or under construction by the Corps of Engineers.

the lower basin to the dairy lands along the New Hampshire and Vermont streams. They result from damage to growing crops, deposition of sand and gravel on flood-plain land, and destruction of stored crops, farm improvements, and farm equipment. The greatest losses occur in the rich truck-farming and tobacco lands in Connecticut and Massachusetts. Other losses

are caused by the destruction of land by gullies and stream-bank erosion resulting in loss of usable land and decreased value of adjoining land.

INDUSTRY

Since industrial development is centered in the flood plains of the Connecticut River and its tributaries, floods invariably cause extensive damages by inundating plants and facilites. Buildings, machinery, and manufactured products suffer direct damage from flood waters and silt. The cost of repairs and cleaning up is included in these damages. Light and power developments, and water-supply, telephone, and telegraph facilities are among those that suffer heavy damages.

URBAN

Direct urban damage results from flooding of residential, commercial, and public buildings. It consists mainly of the cost of repair or replacement, damage to contents, and the cost of cleaning up. Damages are not confined to cities on the main river but are sustained by all municipalities and thickly populated areas on headwater streams with drainage areas as small as 20 square miles.

TRANSPORTATION SYSTEMS

Railroad and highway damages include damage to cuts and fills, bridges, culverts and other drainage structures, and also to operating and maintenance equipment. State, county, and town roads suffer heavy damage from flash floods every year.

INDIRECT DAMAGES

There are other losses in addition to the direct physical damage to properties. They represent the value of the service or use lost, or extra cost made necessary by flood conditions. The farmer suffers such losses because of delay in operations, and loss of income. Business firms that depend on farm products likewise lose through decreased volume of business. Transportation systems, both highway and railroad, suffer indirect damages through interruption of traffic and increased cost of operation. Indirect damage to industry and business includes losses from shutdowns, reductions in business income, and disruption of normal business procedures. Employees lose wages. Expenditures by relief and health agencies to relieve disaster conditions and prevent epidemics are included as indirect damages. Cost of additional policing is also included.

INTANGIBLE DAMAGES

Some of the damages caused by floods are not subject to exact evaluation in monetary terms. Numerous adjustments must be made by the people and communities affected by recurrent flooding. In many cases these adjustments result in intangible losses that affect the local economy. Frequent flooding often checks industrial and urban expansion and may lead to an exodus of people and industries. Loss of income, in addition to decreasing property values, also lowers individual and community morale, affects living standards, and weakens social structure. The ever present threat of inundation creates a mental as well as a physical hazard and prevents full economic and social development of communities located on flood plain lands.

Loss of life by drowning, exposure, and other hardships occurred as a result of major floods in the watershed in 1927, 1936, and 1938. Forty-two people lost their lives in these three major floods. Water supplies were contaminated and widespread typhoid and tetanus anti-toxin injections were required to protect public health.

It is difficult to evaluate the effect of recurrent floods on the recreational phase of the economic life of the watershed. The proximity of recreational areas to stream and

lake shores makes such developments liable to frequent floodwater and sedimentation damage. Increased maintenance costs and decreased use of recreational facilities result from such damage. Destruction of the fish and wildlife resource, as well as the physical deterioration of facilites, reduces the attractiveness of the area for recreational use. A substantial portion of the economy---particularly in the thinly populated northern portion of the watershed--is based on income from providing services to those visiting recreational areas, principally hunters and fishermen.

Although there are many intangible factors entering into an evaluation of damages to the recreation resource, an attempt was made to evaluate them in this watershed. Investigations by survey personnel and by various state agencies indicated floods caused losses to the fish and wildlife population by (1) destroying game habitat and food, (2) drowning both young and adult game anaimals and birds, (3) stranding fish in temporary pools by rapid changes in water level, and (4) destroying fish and their food supply by scouring and silting of stream bottoms. Tentative estimates place the value of these losses at about $434,000 annually. In view of the above-mentioned intangible factors, these estimated losses were not included in the summary of damages in table 1.

CURRENT ACTIVITIES AFFECTING FLOOD PROBLEMS

Several agencies have programs under way that affect runoff and erosion and are deemed of primary importance to the objectives of the Flood Control Act. These programs vary in scope and in effectiveness in correcting unsatisfactory watershed conditions. Some of them, exemplified by the reservoirs, dikes, and pumping stations installed by the Corps of Engineers, are planned primarily for controlling floodwaters. Others, providing technical service, educational assistance, and incentive payments are aimed at improving watershed conditions while increasing production and income for landowners by encouraging the adoption of improved land-management practices. The application of many of the recommended measures and practices results in stabilizing the soil and regulating runoff.

The program of the Crops of Engineers, Department of the Army, was authorized by the Flood Control Acts of June 22, 1936 and June 28, 1938, as amended by subsequent acts including the Acts of August 18, 1941 and December 22, 1944. Under these Acts a flood-control plan, based on confining floodwaters behind large dams or increasing channel capacity at major damage centers by construction of flood walls, has been prepared. This plan proposes the construction of 22 reservoirs and 10 local protection works.

To date, 8 reservoirs and 10 local protection works have been approved and are either constructed, under construction, or awaiting appropriation of funds by Congress. Five reservoirs have been completed and are in operation. They are: Knightville on the Westfield River, Birch Hill on the Millers River, Tully on the Tully River, all in Massachusetts; Surrey Mountain on the Ashuelot River in New Hampshire; and Union Village on the Ompompanoosuc River in Vermont. Local protective works have been completed at eight localities: Hartford and East Hartford, Connecticut; and Springfield, West Springfield, Chicopee, Springdale, Holyoke, and Northampton, Massachusetts. Construction funds have been appropriated for local protection works at Winsted, Connecticut, but are withheld pending fulfillment of requirements for local cooperation. Approval of the construction of three additional reservoirs has been received from the several affected States. The construction of these reservoirs (at Barre Falls on the Ware River, Massachusetts, and Ball Mountain and Townshend on the West River in Vermont) is dependent upon the appropriation of necessary funds by Congress.

Completion of the approved program of 8 reservoirs and 10 local protection works will provide reasonable protection for the principal damage centers in Massachusetts and Connecticut where dike protection is provided. Flood stages will

be reduced substantially on those sections of tributaries that are controlled by reservoirs and to a lesser extent on the main river below its junction with controlled tributaries. It is estimated that completion of the approved program will reduce present average annual damages of $6,285,700 by $3,010,000, leaving $3,275,000 of damages yet to be controlled.

The Department of Agriculture, through its various bureaus, is cooperating with State and local agencies in carrying out programs for the conservation of soil, water, and forest resources. The Forest Service administers and protects 294,000 acres of national-forest land. The state forest-fire protection organizations, in cooperation with the Forest Service under the Clarke-McNary law, have reduced the average annual burn to acceptable limits in recent years and have intensified education and cooperation in the protection field. Cooperative farm forestry projects provide landowners with limited technical service in woodland management on a portion of the watershed. The Production and Marketing Administration provides financial assistance to farmers for carrying out soil- and water-conservation practices. The Soil Conservation Service, in cooperation with soil conservation districts, develops and assists in carrying out farm plans designed to conserve soil and water on individual farms. The entire watershed is included in soil conservation districts

with the exception of a small area in one county in Connecticut. The Department also cooperates with the state extension services and agricultural experiment stations in education and research work in conservation.

The various states and municipalities administer and protect 325,500 acres of forest land. All public land is generally managed in accordance with good timber-conservation principles. In some cases, however, desirable watershed conservation benefits are lost through failure to carry out the measures necessary to heal the physical disturbances caused by harvesting operations.

The annual Federal cost of current Department of Agriculture programs contributing to measurable reductions in water runoff and sedimentation damages is $491,000. This includes the cost of administering and protecting the national forests, cooperative expenditures for fire control, technical service, and reforestation on private forest lands, incentive payments for the installation of improved practices on open land and forest land areas, educational assistance to landowners, and technical service for soil conservation districts.

The various conservation agencies, singly and by cooperative action, have developed and initiated many good practices for the conservation of water and soil resources. Their

primary purpose in this watershed has been the maintenance of soil resources and improvement of crop and timber yield. Such programs have produced some flood control benefits and have developed a public appreciation of the need for an over-all flood control program.

RECOMMENDED PROGRAM

The recommended program is designed to reduce flood and erosion damages by (1) adapting and accelerating those portions of current programs that contribute to measurable reductions in flood runoff and assist in holding the soil in place, and (2) installing the additional measures, practices, and minor structures needed to correct unsatisfactory watershed conditions within a reasonable length of time. In determining the quantities of measures, practices, and minor structures to be installed under the recommended program it was assumed that current programs would be continued at their present rate during the installation period. The expected accomplishments of the current program were deducted from total watershed needs to provide a summary of the work to be accomplished by the recommended program. The program

will be installed in cooperation with state and local governments, and other agencies acceptable to the Secretary of Agriculture.

The program will reduce flood and erosion damages by increasing the infiltration rate and the water-holding capacity of the soil, thereby reducing runoff and erosion. In broad outline, it includes changes in land use and improvements in management measures which are designed to build up and maintain cover and soil conditions that are favorable to watershed protection.

In addition to land measures, attention was given to engineering works such as reservoirs, dikes, and channel improvements. The Corps of Engineers contemplates the construction of local protection works where they are economically justified. Engineering measures to improve stream channels appear to be the only ones justified, aside from those involved in land treatment.

The recommended program of runoff and water-flow retardation and soil erosion prevention includes the following interrelated and interdependent measures.

<u>Forest Land Management</u>

Intensive management practices will be applied on all woodlands for the purpose of improving their hydrologic

condition. The objective of management will be to build up and maintain a forest cover which is effective for developing a good forest floor. Improvement of the forest floor will increase infiltration and soil moisture storage capacities and reduce impermeable freezing in the soil profile during the winter and spring. Under such conditions surface runoff and erosion will be reduced.

Management measures applied to improve woodland hydrologic condition will also develop thrifty, well stocked, productive timber stands which will ultimately provide higher and more sustained income from woodland products. This increase in income will enable woodland owners to participate in the program profitably, and it will more than justify the costs involved.

An expanded program for technical services will be carried out to improve woodland hydrologic conditions. These services will help the landowner in planning and applying woodland practices and integrating the dual objectives of watershed protection and timber production.

Management plans will be prepared for approximately 40,000 individual holdings containing about 3,158,000 acres of private land and 154,000 acres of public land. In brief, they will provide the landowner with basic data on his

forest land and outline the management practices needed to manage the land efficiently and economically.

Technical service and advice on timber marking and logging practices will be provided to minimize clear cutting and destructive logging in harvest cutting areas. Additional technical service will be furnished on about 700,000 acres of private and 95,000 acres of public forest land on shallow soil areas where it is necessary to change stand composition and control stocking density in order to increase soil moisture storage capacity. On such areas the aim will be the development of thrifty, mixed stands of species whose litter not only is highly favorable for humus production but also contributes maximum quantities of organic material to the soil profile.

Technical advice on logging methods will be furnished on about 3,580,000 acres of private land and 774,000 acres of public land to encourage the adoption of improved logging methods which will cause minimum disturbance to woodland hydrologic conditions. Assistance in logging methods will include the proper location and installation of drainage facilites in new logging roads and skid trails as well as the correction of unsatisfactory conditions on old roads in cut-over areas. Many of the existing roads and trails are

sources of aggravated runoff and sedimentation because of poor location, inadequate drainage, and lack of treatment after logging. Correction is necessary if other woodland management practices are to be fully effective. This will be accomplished by the installation of water-spreading devices, small check dams, gully control structures, and culverts.

Livestock will be excluded from approximately 438,000 acres of presently grazed woodland and from about 180,000 acres of open land scheduled for conversion to forest. Grazing reduces the woodland soil infiltration and soil moisture storage capacities by compaction and by destruction of organic matter. Grazing control must be instituted as an essential part of woodland management if the previously mentioned practices are to be effective.

To assure the cooperation of landowners in the installation and maintenance of good woodland management practices, advice and assistance will be given on the utilization and marketing of forest products.

Forest Cover Establishment

A forest cover will be established on approximately 125,000 acres of privately owned open land by planting trees on those areas that will not restock naturally within a

reasonable length of time. The area selected for planting is largely abandoned pasture and hay land that is a major source of surface runoff and erosion. Early establishment of a forest cover on these lands will reduce soil movement, increase infiltration rates, and enlarge soil moisture storage capacity.

Land Acquisition

Approximately 154,000 acres of damaged headwaters land will be acquired by public agencies. These areas, normally well forested, have so been abused that they are a critical floodwater source and need major rehabilitation to restore the watershed cover for effective runoff and sediment control. Productivity will remain low for many years and it is not economically feasible for private owners to manage the land for either watershed protection or timber production. Public acquisition is an essential first step in insuring the establishment of necessary rehabilitation measures and providing continuity of management.

Approximately 45,000 acres of the area recommended for public purchase is located within established national forest purchase units and will be acquired by the Federal Government. The remaining 109,000 acres will be purchased

by state or other public agencies. All land will be acquired by voluntary sales on the part of the owner in accordance with state and Federal legislation.

Gully Stabilization and Sediment Control

Approximately 1,150 erosion control structures including small check dams, gully structures, and culverts will be installed as part of the water disposal system or for gully stabilization. Concentration of runoff requires special erosion control structures to protect channels or natural drainageways from gullying and to furnish protection to railroad and highway ditches. New and larger culverts will be necessary to discharge runoff safely under railroad and highway fills. The establishment of this measure will reduce the rate of gully erosion in existing drainageways and permit the installation of adequate water disposal systems which will materially reduce sheet and gully erosion on the fields protected.

Subwatershed and Farm Waterways

Adequate systems for the disposal of runoff water are a necessary part of the program to reduce floodwater and sediment damage. Approximately 500 miles of outlets and waterways will be established to provide for the safe disposal of runoff from terrace and diversion systems. This will result in reduced gully erosion and sediment protection. The outlets

and waterways will be vegetated and will include broad meadow strips and constructed channels. Supporting structures, required as a part of the disposal system, are included with the recommended erosion control structures.

Field Diversions and Terraces

Approximately 1,648 miles of diversions and terraces will be installed to provide for intercepting surface runoff from sloping land and carrying it in properly designed and constructed channels across the slopes to an outlet or waterway. Terraces will be installed on the more moderately sloping land with short rotations. Diversions will be installed on the steeper slopes and in conjunction with less intensive rotations. The installation of these measures will furnish protection from damaging runoff to the lands lying immediately below and will significantly reduce erosion and sediment production.

Contour Strip Cropping

The practice of growing hay or other close-growing and soil-conserving crops in contour strips, alternating with clean-tilled or soil-depleting crops, will be applied on approximately 471,000 acres of cropland. Contour tillage operations in conjunction with contour strip cropping will provide appreciable surface detention storage for runoff.

Such a system will, in addition, keep at least half the sloping cropland in erosion-resisting crops at all times, lessen the amount and velocity of runoff and the concentration of water in gullies or channels, thereby reducing the losses of soil by erosion.

<u>Establishing Perennial Hay</u>

Approximately 25,700 acres of perennial grasses and legumes will be established to protect land not suitable for row crops and to protect such measures as diversions, and outlets and waterways. This measure through increasing the infiltration rate, will reduce runoff and flood damage and, by protecting other measures, will reduce gully erosion and the resulting sedimentation.

<u>Cover Crop Establishment</u>

The practice of growing temporary crops to provide vegetative cover on land following the harvesting of clean tilled crops until the next regular crop is planted will be applied on approximately 67,900 acres of cropland. A satisfactory vegetative cover will lessen the impact of raindrops on the soil, thus reducing erosion and maintaining the soil in condition to readily absorb water. The organic matter added to the soil by cover cropping will increase its water holding capacity.

Crop Rotations

Proper crop rotations will be established on 20,400 acres to control accelerated erosion and aid in preventing runoff.

Crop-residue Management

Crop-residue management will be practiced on 23,800 acres to aid in preventing soil erosion and to make conditions favorable for maximum infiltration of water following harvesting of crops.

Pasture Management

Pasture management consisting of mowing to remove weeds and mature grasses, the scattering of droppings, and the control of grazing intensity will be applied on approximately 151,000 acres of pasture so that the improved vegetative cover will prevent erosion and increase infiltration. Fences will be used to facilitate the control of grazing intensity. Brush or other obstructions to mowing will be removed where feasible.

Pasture Contour Furrows

Level furrows or small level terraces will be installed on approximately 43,700 acres of pasture land. The furrows will be spaced and constructed so that approximately one-half inch of runoff will be held in detention storage.

In addition to reducing runoff, the installation of this measure will control erosion on sediment source areas.

Stream-bank Stabilization

Approximately 1,662 miles of eroding stream bank will be stabilized to control erosion and reduce sediment loads.

Stream-channel Improvement

Special measures and structures will be used to control movement of water and debris in mountain stream channels and to improve channel conditions throughout the watershed. Included are such structures as minor dikes, check dams, and settlement basins, and such measures as channel straightening and dredging.

Educational Assistance

Educational assistance will be made available to landowners to acquaint them with the program and its objectives and benefits. Intensified educational efforts will be directed toward acquainting landowners with the specific practices and measures essential for controlling runoff and erosion, and showing them how to integrate these measures into land-management programs to produce the greatest benefit over a long period.

Direct Aids

Direct aids will be available to all landowners and farm operators in the watershed to assist them in applying or installing those soil and water conservation measures needed on their farms which otherwise would not be carried out to the desired extent. Assistance offered under this phase of the program will be integrated with the educational and technical services to promote a complete and effective program of water-flow retardation and erosion prevention. This assistance will generally not exceed 50 percent of the out-of-pocket cost of carrying out the approved practices and will be administered in such a manner as to obtain the greatest possible conservation with available funds.

Technical Services

Technical services will be provided to aid the landowner in planning, integrating, and applying the recommended measures in an effective program of water-flow retardation and erosion prevention.

Testing Program Effectiveness

To test the effectiveness of the flood-control program, hydrologic stations will be installed and maintained. These stations will be installed on small watersheds representative of the general land-use conditions to be improved. Analysis

of the data collected at these stations will provide action-program administrators with information indicating necessary changes in application of program measures.

COST OF RECOMMENDED PROGRAM

INSTALLATION

The total cost of installing the recommended program is estimated to be $31,471,000. Of this amount, the Federal Government will spend about $17,563,000, other public agencies about $4,728,000, and private landowners about $9,180,000.

These cost estimates are based on 1949 prices of labor, equipment, and materials. They are computed on the assumption that the program measures will be installed during a 20-year period.

The Federal Government will bear the entire cost of the following activities: administering and testing recommended program measures; acquiring lands for watershed protection purposes within present national forest boundaries; installing measures and improvements on existing national forest land and on lands to be acquired; and providing technical assistance for planning and installing open land measures on private lands. The Federal Government will also pay

Table 2.--Estimated cost of installing recommended program, 1949 prices

Measure	Quantity & units		Installation
1. Forest land management			
a. Private lands	3,580,000	acres	$12,629,000
b. National-forest lands	340,000	acres	366,000
c. Other public lands	434,000	acres	773,000
2. Forest cover establishment	124,700	acres	2,981,000
3. Land acquisition			
a. National forests	45,000	acres	540,000
b. Other public	109,000	acres	1,083,000
4. Structures	1,151	each	750,000
5. Outlets and waterways	500	miles	670,000
6. Field diversions and terraces	1,648	miles	698,000
7. Contour strip cropping	471,200	acres	1,182,000
8. Establish perennial hay	25,700	acres	1,577,000
9. Cover crop establishment	67,900	acres	372,000
10. Crop rotations	20,400	acres	14,000
11. Crop residue management	23,800	acres	12,000
12. Pasture management	151,000	acres	2,218,000
13. Pasture contour furrows	43,700	acres	702,000
14. Stream-bank stabilization	1662 1,562	miles	3,102,000
15. Stream-channel improvement	480	miles	1,802,000
			$31,471,000

up to one-half of the cost of technical services for improving forest cover on private lands and up to one-half of the cost of the additional educational assistance needed on private lands.

Local public agencies will bear the cost of acquiring other lands for watershed protection purposes and for installing, operating, and maintaining measures on existing other public lands and on lands to be acquired. In addition they will provide one-half of the cost of technical services for improving forest cover on private lands and one-half of the cost of additional educational assistance.

The Federal Government will bear from 75 to 100 percent of the cost of installing the following measures on private land: stream-bank stabilization, contour strip cropping, field diversions and terraces, outlets and watercourses, structures, and pasture contour furrows. In addition, the Federal Government will pay for carrying out on such lands about 65 percent of the cost of stream-channel improvement, about 50 percent of the cost of establishing a forest cover, and about 27 percent of the cost of pasture management.

OPERATION AND MAINTENANCE

The cost of operating and maintaining the measures included in the recommended program will increase each year from the

beginning of the second year of the installation period until it reaches a maximum of $2,238,000 of which the annual Federal cost will be $281,000, other public cost $291,000, and private cost $1,666,000.

BENEFITS FROM THE PROGRAM

The average annual benefit from the recommended program when it reaches maximum effectiveness is estimated at $16,675,000 (table 3). Attainment of this benefit is dependent on the installation and proper maintenance of all phases of the program. Three types of benefits will accrue from the program: (1) reduction in flood and sediment damages; (2) conservation benefits, which are measured by the increased income attributable to the land measures; and (3) intangible benefits such as prevention of loss of life. Only the first two types were included in the direct monetary determination of the benefits and costs.

FLOOD AND SEDIMENT DAMAGE REDUCTION

The average annual benefit resulting from reduction of flood and sedimentation damage is estimated at $754,000. This includes both direct and indirect benefits from (1) reduction in frequency and severity of floods on agricultural,

Table 3.--Estimated annual benefits when the program is fully effective

Kind of benefit	Value
Flood and sediment damage reduction:	
Direct benefits:	
Reduction of floodwater damage	
Agricultural	$ 68,000
Urban 1/	100,000
Industrial 2/	88,000
Transportation systems 3/	156,000
Reduction of stream-bank erosion and sediment damage 4/	36,000
Total direct benefits	$ 448,000
Indirect benefits	306,000
Total flood and sediment reduction benefits	$ 754,000
Land enhancement	142,000
Conservation benefits: Benefits to landowners through decreased crop-production costs, increased crop, pasture, and forest products yields, and reduction of soil loss	15,779,000
Total benefits	$16,675,000

1/ Includes residential, commercial, and public benefits.
2/ Includes industrial and utility benefits.
3/ Includes highway and railroad benefits.
4/ Includes benefits from decreased road maintenance, reservoir sedimentation, and loss of land.

urban, and industrial land in flood plains, (2) reduction in flood and sedimentation damages to railroads and highways, and (3) reduction in loss of land.

LAND ENHANCEMENT

Land enhancement benefits in the amount of $142,000 annually will accrue as a result of reducing the frequency and severity of flooding on those agricultural flood plains where the land use is less intensive than its capability would otherwise permit.

CONSERVATION BENEFITS

Conservation benefits will accrue to landowners and operators as a result of improved land management. The average annual benefit is estimated at $15,779,000. It will result chiefly from (1) reductions in crop-production costs, (2) increased crop production due to the water-conservation effects of program measures, (3) increased pasture yields, (4) reduction in soil loss, (5) increased timber quality and volume cut per acre, and (6) increased value of wood products.

INTANGIBLE BENEFITS

Many of the benefits that will accrue from installation of the recommended program are not susceptible of economic evaluation. They are, however, very important. Some

of the intangible benefits, especially those concerned with personal and social welfare, are obviously desirable. Such benefits are (1) improved public safety and welfare through a reduction of the extent and frequency of flood flows, (2) gradual development of higher standards of living through an increased and stabilized income, and (3) improvement of morale through decreased mental suffering and physical inconvenience caused by recurrent flooding.

Additional intangible benefits which will accrue have not been evaluated. For example, the improvement of vegetative cover will create a more attractive watershed for recreational activities; provide more food and better habitat for game birds and animals; will improve water habitat for fish through better regulation of stream flow; and reduce flood damage to fish and wildlife resources. Accordingly, the installation of the recommended program will provide for a needed expansion of the recreation resources of this densely populated region and result in a major contribution to its general economy.

Other unevaluated benefits include those involved in the harvesting, transportation, and processing of the increased volume of raw materials produced on well managed agricultural and forest land. For example, the value of increased production to the landowner in the form of "stumpage" was

included in the benefit calculations. This is merely the first link in an expanding chain of values that accrue from the utilization of timber. Pulpwood valued at $3 per cord on the stump may finally emerge from a paper mill in a product worth $50; and sawlog material valued at $6 per thousand board feet on the stump may emerge from the sawmill in lumber worth $75 to $100 per thousand board feet and later from a box factory or furniture factory at values still higher. None of this "value added" by harvesting and utilization has entered into the benefit calculations. The growing timber, however, is one of the indispensable factors that create such values. The mere stumpage value is not an adequate criterion for estimating the true worth of raw material supply--the key to a whole structure of dependent economic activities.

COMPARISON OF BENEFITS AND COSTS

Benefits are compared with costs by expressing both in terms of average annual value. The annual cost of the program is $2,892,800 (table 4).

Table 4.--Average annual cost of program

Source of funds	Program installation 1/	Operation and maintenance 2/	Total
Federal	$ 439,500	$ 229,800	$ 669,300
Other public	118,500	241.400	359,900
Private	367,000	1,496,600	1,863,600
Total	$ 925,000	$ 1,967,800	$ 2,892,800

1/ Federal and other public installation costs converted to an annual basis at 2½ percent rate. Private costs converted at 4 percent rate.

2/ Timber marking costs discounted at 2½ and 4 percent rate as they are incurred gradually over a period of years.

The average annual benefit from the recommended program is $10,808,000 (table 5).

Table 5.--Average annual benefits from the program

Type of benefit	With program fully effective	Discounted to present
Flood reduction	$ 896,000	$ 734,000
Conservation	15,779,000	10,074,000
Total	$ 16,675,000	$ 10,808,000

Costs and benefits are compared in table 6, both in terms of current (1949) prices and on a basis reflecting "normal" price levels in time of moderate employment and economic activity.

Table 6.--Comparison of annual benefits and costs

Basis for comparison	Cost	Benefit	Ratio of benefits to cost
Current prices	$2,892,800	$10,808,000	3.7 : 1
Normal prices 1/	$1,923,400	$ 6,162,000	3.2 : 1

1/ Price indices used in the calculation of costs and benefits include:

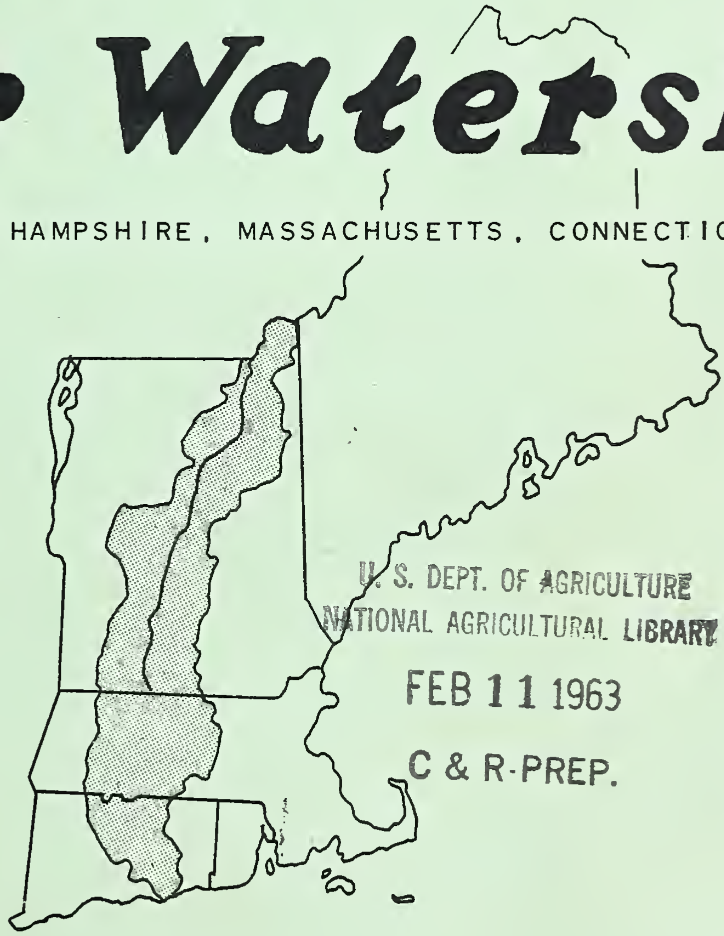
	1949	Normal 1955-65
Prices received by farmers	249	150
Wholesale lumber index	286	145
Construction costs	477	325
Prices paid by farmers	238	155
Wholesale commodities	155	106

APPENDIX

SURVEY REPORT

CONNECTICUT River Watershed

VERMONT, NEW HAMPSHIRE, MASSACHUSETTS, CONNECTICUT



PROGRAM FOR RUNOFF AND WATERFLOW RETARDATION
AND SOIL EROSION PREVENTION

U.S. DEPARTMENT OF AGRICULTURE

1951

Certain discrepancies exist between the report and these appendixes in connection with the acreage to be treated by forest land measures, the cost of such measures, the benefits to be derived from them, and the benefit-cost ratio of the recommended program. Details concerning these discrepancies are shown on page 87.

CONTENTS

LAND FACTORS IN RELATION TO FLOOD PROBLEMS

To develop a flood-control program for the Connecticut River watershed (fig. 1), one must go to the root of the trouble: the land where the rain falls and the snow melts. Studies on this land must go even deeper, into the soil, to determine the factors that are important in relation to floods. It is necessary to know how the soil is composed, what cover it has on it, how it is used, and numerous more complex factors that are the concern of specialists such as hydrologists.

According to the best knowledge today, there are three major soil factors related to flood problems. These are:

1. Soil-cover complexes
2. Infiltration rates
3. Moisture-holding capacity

Table 1.--Present land use in the Connecticut River watershed

Cover	Area		Proportion of total area
	Acres	Percent	Percent
Farm land:			
Cropland (incl. hay)	869,000	25.7	--
Pasture	675,000	19.9	--
Cropland, idle	30,000	.9	--
Other	96,000	2.8	--
Woodland, grazed	807,000	23.8	--
Woodland, ungrazed	910,000	26.9	--
All farm land	3,387,000	100.0	47.5
Non-farm forest	3,063,000	100.0	42.9
Miscellaneous:			
Road and urban	526,000	76.8	--
Water area	159,000	23.2	--
All miscellaneous	685,000	100.0	9.6
Total, drainage area	7,135,000	--	100.0

Figure 1

CONNECTICUT RIVER WATERSHED
VT., N.H., MASS., CONN.
74°00'
73°00'
72°00'
71°00'
45°00'
44°00'
43°00'
42°00'
QUEBEC
VERMONT
BEECHER FALLS
STRATFORD
ORLEANS
ESSEX
COOS
WHITE MOUNTAIN NATIONAL FOREST
ST JOHNSBURY
LITTLETON
WASHINGTON
CALEDONIA
ORANGE
ADDISON
GREEN MOUNTAIN NATIONAL FOREST
GRAFTON
WHITE RIVER JUNC
WINDSOR
SULLIVAN
MERRIMACK
GREEN MOUNTAIN NATIONAL FOREST
BELLOWS FALLS
WINDHAM
CHESHIRE
KEENE
Mt Monadnock
BRATTLEBORO
HILLSBORO
BENNINGTON
RUTLAND
VT
MASS
NH
MASS
FRANKLIN
GREENFIELD
Quabbin Reservoir
WORCESTER
HAMPSHIRE
NORTHAMPTON
HOLYOKE
CHICOPEE
SPRINGFIELD
HAMPDEN
BERKSHIRE
BERKSHIRE HILLS
MASS
CONN
LITCHFIELD
TOLLAND
HARTFORD
EAST HARTFORD
NEW BRITAIN
NEW HAVEN
MIDDLESEX
NEW LONDON
LONG ISLAND SOUND
SCALE OF MILES
10 5 0 10 20 30
LOCATION MAP
LONG ISLAND SOUND
ATLANTIC OCEAN
U.S. DEPT. OF AGRICULTURE-FOREST SERVICE
NORTHEASTERN FOREST EXP. STATION
MAP OF WATERSHED

SOIL-COVER COMPLEXES

In the Connecticut watershed there are several different kinds of soil, and many different kinds of cover on those soils. Many different combinations of soil and cover are found in the watershed. These combinations are called "soil-cover complexes"; and they are used in evaluating data.

On farm land.--The soil-cover complexes on farm land were determined from sample farm surveys, supplemented by published data on soils and cover. On the upper portion of the watershed (Vermont and New Hampshire) 51 sample farms, representing the major types of farming, were selected at random from a 20-percent sample group. The sample farms were surveyed in the field, and a base map was prepared for each farm. These surveys were expanded to a watershed basis; in doing this, soil-survey maps were used to determine the areal extent of the soils, and Bureau of Census data were used to expand cover types.

In Massachusetts and Connecticut a detailed survey was made on 52 farms selected to represent predominant types of agriculture in the area. The data collected were combined with data from available soil and type maps, and the survey was expanded to a watershed basis.

On forest land.--In Vermont and New Hampshire the soil-cover complexes of the forested areas were obtained from field surveys that determined soils and forest types. These data were expanded to give totals for the watershed area included in these States. In Connecticut and Massachusetts the soil-cover complexes were obtained by superimposing land-use maps on soil survey maps; this furnished the forest area by soil types. Field surveys, published data, and information from local agencies provided information used in breaking down forest area by type and condition. All this data was adjusted to Bureau of Census 1945, Agricultural Statistics.

Soil Complexes

A study of the soils in the watershed indicated that infiltration rates could be applied to the soils on the basis of two depth classifications and two textural classifications. Combinations of these provided four soil complexes:

Table 2.--Distribution of soil in Connecticut River Watershed, by texture and cover

Watershed	Total area	Forest land								Open land								Miscellaneous	
		Shallow soils				Deep soils				Shallow soils				Deep soils					
		Light texture		Medium texture		Light texture		Medium texture		Light texture		Medium texture		Light texture		Medium texture			
	Acres	Acres	Per-cent	Acres	Per-cent	Acres	Per-cent	Acres	Per-cent	Acres	Per-cent	Acres	Per-cent	Acres	Per-cent	Acres	Per-cent	Acres	Per-cent
Ammonoosuc	257,300	28,303	11	59,179	23	38,595	15	79,763	31	2,573	1	12,865	5	2,573	1	23,157	9	10,292	4
Mascoma	124,800	12,480	10	24,960	20	18,720	15	41,184	33	1,248	1	4,992	4	1,248	1	13,728	11	6,240	5
Sugar	175,400	28,064	16	17,540	10	50,866	29	29,818	17	-	0	7,016	4	1,754	1	22,802	13	17,540	10
Ashuelot	268,800	45,696	17	29,568	11	94,080	35	56,448	21	-	0	10,752	4	-	0	18,816	7	13,440	5
Passumpsic	324,500	22,715	7	58,410	18	22,715	7	64,900	20	3,245	1	6,490	2	51,920	16	77,880	24	16,225	5
Stevens	31,400	1,884	6	6,280	20	1,570	5	4,710	15	314	1	628	2	5,024	16	9,734	31	1,256	4
Wells	63,400	5,072	8	13,948	11	6,974	11	19,020	30	634	1	1,268	2	5,072	8	8,876	14	2,536	4
Waits	93,400	7,472	8	19,614	21	4,670	5	13,076	14	934	1	1,868	2	14,944	16	27,086	29	3,736	4
White	454,400	22,720	5	113,600	25	18,176	4	99,968	22	4,544	1	9,088	2	49,984	11	113,600	25	22,720	5
Ottauquechee	142,700	9,989	7	32,821	23	9,989	7	34,248	24	1,427	1	2,854	2	17,124	12	25,686	18	8,562	6
Black	126,100	6,305	5	32,786	26	6,305	5	36,569	29	2,522	2	2,522	2	12,610	10	21,437	17	5,044	4
Saxton	49,900	2,495	5	12,974	26	2,994	6	16,467	33	499	1	998	2	3,992	8	6,986	14	2,495	5
West	270,700	13,535	5	70,382	26	18,949	7	105,573	39	2,707	1	5,414	2	16,242	6	24,363	9	13,535	5
Deerfield	425,600	25,536	6	106,400	25	29,792	7	140,448	33	8,512	2	17,024	4	29,792	7	46,816	11	21,280	5
Millers	249,600	47,424	19	27,456	11	84,864	34	49,920	20	2,496	1	9,984	4	2,496	1	7,488	3	17,472	7
Chicopee	463,400	74,144	16	32,438	7	143,654	31	60,242	13	-	0	9,268	2	18,536	4	92,680	20	32,438	7
Westfield	332,800	43,264	13	33,280	10	103,168	31	83,200	25	3,328	1	3,328	1	19,968	6	26,624	8	16,640	5
Above 15 Mile Falls	983,700	88,533	9	216,414	22	157,392	16	354,132	36	9,837	1	19,674	2	19,674	2	49,185	5	68,859	7
Farmington	389,800	62,368	16	15,592	4	163,716	42	46,776	12	3,898	1	7,796	2	38,980	10	31,184	8	19,490	5
Scantic	73,000	5,840	8	1,460	2	27,010	37	6,570	9	730	1	2,190	3	7,300	10	21,170	29	730	1
Hockanum	52,600	2,104	4	526	1	22,618	43	4,734	9	-	0	-	0	5,786	11	5,260	10	11,572	22
Salmon	97,300	18,487	19	-	0	57,407	59	1,946	2	-	0	-	0	11,676	12	5,838	6	1,946	2

1. Light-textured deep soils
2. Medium-textured deep soils
3. Light-textured shallow soils
4. Medium-textured shallow soils

The texture of the soil--determined by the relative amounts of sand, silt, clay, and organic matter--is a characteristic that greatly influences the rate at which water will infiltrate into the soil and the amount of water the soil will store. Light-textured soils range from fine gravel to fine sandy loam. Medium-textured soils range from very fine sandy loam to silt loam. (Heavy soils were not significant, since they occupy less than 3 percent of the watershed; so they were grouped with the medium-textured soils.)

Texture classifications were obtained from existing soil surveys for all the land except the more mountainous and generally forested areas, where no textural breakdown was available. The textures of these soils were determined from field studies, which indicated that the texture groups are distributed in shallow soils in generally the same ratio as in deeper soils.

Depth classifications were made according to the hydrological capabilities of the soil. Deep soils are defined as being able to hold the maximum amount of rainfall; this capacity was based on analyses of storms in the watershed and infiltration rates of the soil. Shallow soils, because of an impermeable layer of bedrock, will not store the maximum amount of rainfall; thus they contribute more directly to peak flow. The breakdown between deep and shallow soils was obtained from soils bulletins.

Cover Complexes

For purposes of land-use planning and to meet hydrological requirements the major cover complexes in the sample watersheds were grouped as follows:

1. Open land.

    a. Clean-tilled cropland.
    Used for annual crops such as potatoes, corn, millet, beans, tobacco.

Table 3.--Distribution and condition of cover in the Connecticut River watershed.

Watershed	Total area	Land use distribution			Forest land								Open land				
					Areal distribution by types					Weighted hydrologic condition			Areal distribution by use			Condition of pasture	
		Forest land	Open land	Misc.	Long-lived hardwoods	Mixed woods	Temporary hardwoods	Spruce, fir hemlock	White pine	Good	Poor	Grazed	Tilled	Pasture	Hay	Lightly grazed	Heavily grazed
	Acres	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Ammonoosuc	257,300	80	16	4	20	19	21	32	8	59	26	15	5	45	50	50	50
Mascoma	124,800	78	17	5	20	19	21	33	7	56	27	17	6	29	65	50	50
Sugar	175,400	72	18	10	8	27	0	19	46	51	28	21	6	33	61	50	50
Ashuelot	268,800	84	11	5	19	17	5	30	29	61	32	7	10	45	45	50	50
Passumpsic	324,500	52	43	5	32	5	14	48	1	25	15	60	7	49	44	45	55
Stevens	31,400	46	50	4	32	5	14	48	1	27	17	56	4	56	40	45	55
Wells	63,400	71	25	4	32	5	14	48	1	32	22	46	4	60	36	45	55
Waits	93,400	48	48	4	32	5	14	48	1	33	22	45	4	56	40	45	55
White	454,400	56	39	5	65	12	1	11	11	39	25	36	5	50	45	45	55
Ottauquechee	142,700	61	33	6	64	6	1	21	8	42	26	32	3	61	36	45	55
Black	126,100	65	31	4	54	7	7	17	15	42	26	32	6	49	45	45	55
Saxton	49,900	70	25	5	54	7	7	17	15	49	35	16	8	40	52	45	55
West	270,700	77	18	5	54	7	7	17	15	49	35	16	6	44	50	45	55
Deerfield	425,600	71	24	5	12	17	9	9	9	50	34	16	8	46	46	45	55
Millers	249,600	84	9	7	56	12	20	2	10	60	25	15	22	33	45	45	55
Chicopee	463,400	67	26	7	60	9	26	0	5	59	24	17	15	47	38	45	55
Westfield	332,800	79	16	5	67	5	21	0	7	55	28	17	19	38	43	45	55
Above 15 Mile Falls	983,700	83	10	7	26	12	17	40	5	62	35	3	10	50	40	50	50
Farmington	389,800	74	21	5	67	5	21	0	7	51	34	15	6	42	52	23	77
Scantic	73,000	56	43	1	60	9	26	0	5	59	28	13	32	35	33	29	71
Hockanum	52,600	57	21	22	65	7	23	0	5	58	24	18	27	33	40	30	70
Salmon	97,300	80	18	2	75	9	22	0	4	66	23	11	7	41	52	48	52

b. Rotation and permanent hay land.
   Used for forage crops, grasses, legumes.

c. Pasture
   Any open lands used only for grazing were divided as follows:

   (1) Heavily grazed pasture with an inadequate ground cover where there is severe erosion and soil compaction as a result of excessive use.

   (2) Lightly grazed pasture with adequate ground cover where there is little erosion or soil compaction.

d. Idle land.
   Land that provides no economic returns to the owner. It includes abandoned or temporarily unused crop, hay, and pasture land as well as swampy, excessively rocky or gullied open land which cannot be used for producing crops or forage.

e. Other land.
   House yards, barnyards, roads, etc.

2. Forest land.

Includes all farm woodlots, grazed and ungrazed; other timber tracts, natural or planted; and cut-over land with young growth that has or will have value as wood or timber. The forest associations used include the forest types recognized and described by the Society of American Foresters (1932) and regrouped for hydrological analysis by the survey party.

a. Long-lived hardwoods.
   Generally this association represents a transition type between central hardwoods and northern hardwoods. Oaks are the more abundant and important species in the southern part of the watershed; and beech, birch, and maple are more important in the north. This association includes all hardwoods in the area except those of a short-lived temporary nature.

b. Mixedwood.
   Includes both softwoods and hardwoods, neither of which makes up a predominant part (80 percent) of the stand. In the south red maple and oak are the most common hardwoods, and white pine and hemlock the most common softwoods. In the northern part of the watershed and

at higher altitudes this type is generally composed of spruce, fir, and hemlock, combined with northern hardwoods. In central New England the two extreme types merge in a varying association of all the above-mentioned species.

c. Softwoods.
All the recognized softwood types in the watershed. All of these associations are composed of 80 percent or more of softwoods. Within the area, three main types are recognized: spruce-fir-hemlock, white pine, and white pine-hemlock.

d. Temporary hardwoods.
This type represents mostly abandoned crop and pasture land that is reverting to woodland. There is also a relatively small but important acreage of forest land, either burned over heavily and frequently cut, or both, which is occupied by temporary species. The most characteristic trees in this short-lived association are gray birch, aspen, and pin cherry.

The present hydrologic condition of each of these soil-cover complexes was determined and used in the hydrologic evaluation of the watershed discussed in the hydrology section of this appendix. Application of the recommended program measures and practices changed the areal distribution of some of the soil-cover complexes as well as the hydrologic condition. These changed conditions were used in the hydrologic evaluation of the watershed in the future.

HYDROLOGIC CONDITIONS

The present hydrologic condition of the watershed is the result of treatment given the land while growing and harvesting crops in the past. Previously applied management practices have affected the depth and structure of the soil mantle, the amount of organic matter in the soil, and the infiltration capacity of the surface layer. Most land management activities have been aimed principally at securing maximum agricultural crop and forest product returns. Little attention has been paid to maintaining optimum soil and water relationships in the soil profile. Consequently hydrologic conditions on open land as well as on forested areas have deteriorated over the past several hundred years.

Forest Land

Past forest fires, poor cutting and logging practices, and woodland grazing have impaired much of the forest land for watershed protection purposes. Studies indicate, for example, that forest floor conditions break down rapidly after an area has been subjected to widespread clear cutting and other abuses. The extent of deterioration is apparent after a study of present forest conditions. Many relatively young stands are clear-cut of all merchantable volume. Over 30 percent of the woodland area is occupied by stands less than 50 years old. A large proportion of these stands, as well as those in older age classes, are understocked and do not provide the complete ground shade needed to maintain and improve hydrologic conditions. About 16 percent of the forest area is occupied by stands of temporary species which are less efficient than the permanent species for developing good forest floor conditions. Active erosion occurs on many of the old skid and haul roads used in past cutting operations. These have not revegetated and are primary sources of sediment. They also serve as wet weather drainage channels which concentrate surface runoff and produce most of the flood runoff from forested areas.

Hydrologic conditions in a given forest type are either good, poor and ungrazed, or poor and grazed, depending on the combination of factors which affect hydrologic condition. Measurable factors include stand age, density, humus type and depth, soil texture, presence of livestock grazing, and extent and physical condition of old logging roads. Good hydrologic conditions occur when the forest floor is covered with a well developed humus underlain by a friable loose soil. Poor conditions occur when the humus layer is thin or of a compact type, especially when underlain with a more or less compact mineral soil.

The distribution of land in these three categories was determined by a study of 300 randomly selected sample plots. These same plots were also used to study the distribution of age classes, soil textures, and the extent and condition of old logging roads within the above-mentioned categories. These data provided a basis for computing the percentage of the sample area in the several hydrologic conditions by forest types, by age class and by soil texture. While most of the plots fell within the long-lived hardwood and the temporary hardwood types, enough samples were available in the other types to indicate that the distribution of good and poor forest condition is similar within all types.

Data from the above-mentioned survey, supplemented by that from existing soil surveys and from the 1944 forest reappraisal survey, provided the basis for determining the distribution of hydrologic conditions within the forest area of the watershed as follows:

> The forest area of each subwatershed was broken down by forest types and stand size classes by means of percentages based on reappraisal data. The areal distribution of stand size classes was converted to an age class distribution in accordance with the relationship between stand size and age found on the 300 sample plots. These data, weighted by the distribution of light and medium textured soils, and by the hydrologic conditions found on the sample plots, provided a basis for determining the areal extent of the good and poor hydrologic condition in the subwatershed. The areal extent of the poor condition was further proportioned between the grazed and ungrazed category in accordance with the distribution of grazed woodlands determined by a sample farm survey.

Open Land

Intensive cultivation, tillage without regard to direction of slope, and failure to maintain organic content of the soil have impaired the hydrologic condition of open land areas. Over grazing of pasture has resulted in removal of the vegetative cover, reduction of organic matter in the soil, and widespread soil compaction. Improper use of land, particularly for pasture on steep slopes, is quite common in portions of the watershed.

Present land practices have accelerated stream-bank erosion. Many stream banks have been cleared of protective cover. This, coupled with increased flood flows, concentration of stock along streams, and plowing to the bank has caused severe erosion and loss of land.

The hydrologic condition of open lands was determined by surveys of approximately 100 sample farms. Data collected on the sample farms were expended to a watershed basis.

INFILTRATION CAPACITY

Infiltration capacity is defined as the maximum rate at which water will enter the surface of the ground. It is measured with an infiltrometer and expressed in terms of inches of water per hour. An FA type of infiltrometer was used for determining the relative infiltration rates of the various soil-cover complexes. In all, 41 measurements were made on 15 different soil-cover complexes; 7 on light textured soils and 8 on medium textured soils. At least 2 determinations were made on each complex studied. Rates used in the hydrologic evaluation are shown in tables 4 and 5. Infiltration rates for the soil-cover complexes for which no field measurements were made were interpolated or were derived from data collected elsewhere.

As indicated previously, infiltration capacity is influenced by the texture and structure of the soil, by cultural operations on open land, and by the type of timber harvesting operations and livestock grazing in woodlands. Low winter temperatures also affect infiltration by forming a layer of concrete frost which seals the soil profile against water entry.

In order to reduce surface runoff, a major contributor to flood flow, it is necessary that the infiltration capacity of the soil-cover complexes be increased as nearly as possible to the point where the surface layer will accept precipitation of maximum intensities. Meeting this objective will provide a maximum reduction of surface runoff from areas of deep soil where the soil mantle is capable of storing all water which enters it from the surface.

A large portion, nearly 1,700,000 acres of the watershed, however, has a shallow, porous soil mantle, usually underlain by impermeable rock. Under such conditions the soil moisture storage capacity is limited. It fills rapidly and precipitation in excess of storage capacity passes off as surface flow. A reduction in volume of runoff can be secured by building up the storage capacity of the soil mantle. This will be done in woodlands--occupying most of the shallow soil areas--by applying management measures and practices favoring the development of thrifty mixed stands, composed of species that are effective in building up the humus layer and that will produce maximum amounts of organic matter to improve soil and water relationships in the soil profile. Cultural operations in woodlands can be guided to secure an increase in storage capacity in the soil mantle within a period of 20 to 30 years.

Table 4.--Infiltration rates on forest land in inches per hour by soil-cover complexes

Soil and cover type	Summer rates			Winter rates		
	Good forest	Poor forest		Good forest	Poor forest[1]	
		Ungrazed	Grazed		Ungrazed	Grazed
Light textured soils:						
Hardwoods[2]	2.52	1.03	0.29	2.52	0-1.03	0-0.29
Mixedwoods	2.38	.99	.29	2.38	0-0.99	0-0.29
Hemlock-spruce-fir	2.16	.91	.29	2.16	0-0.91	0-0.29
Pine-hemlock	1.86	.81	.29	1.86	0-0.81	0-0.29
Medium textured soils:						
Hardwoods[2]	2.36	1.17	.57	2.36	0-1.17	0-0.57
Mixedwoods	2.17	1.10	.57	2.17	0-1.10	0-0.57
Hemlock-spruce-fir	1.98	1.04	.57	1.98	0-1.04	0-0.57
Pine-hemlock	1.70	.95	.57	1.70	0-0.95	0-0.57

1/ Dependent on incidence of impermeable frost.

2/ Includes long-lived and temporary hardwoods.

Table 5.--Infiltration rates on open land in inches per hour, by soil-cover complexes

Soil and cover type	Summer rates		Winter rates[1]
	Present	Future	
Light-textured soils:			
Cropland, clean-tilled	0.25	0.32	0 - 0.32
Pasture, lightly grazed[2]	.70	.70	0 - .70
Pasture, heavily grazed	.29	--	0 - --
Hay land	.75	.75	0 - .75
Other	.20	.20	0 - .20
Medium-textured soils:			
Cropland, clean-tilled	.21	.26	0 - .26
Pasture, lightly grazed	.57	.57	0 - .57
Pasture, heavily grazed	.15	--	0 - --
Hay land	.58	.58	0 - .58
Other	.20	.20	0 - .20

1/ Dependent on incidence of impermeable frost.
2/ Includes idle land.

The presence of impermeable frost is extremely important in both shallow and deep soil areas. Studies indicate rather conclusively that a concrete type of frost effectively prevents infiltration into the soil in most open lands and in those woodlands that are compacted by grazing or are poorly stocked and have a poor forest floor. Woodland soils with a well developed humus layer and a good mixture of organic matter in the soil often freeze but usually with a granular type of frost which does not affect infiltration.

Rates Applicable

The above infiltration rates were applied in the hydrologic evaluation of the watershed under present conditions and as it will be with the recommended program installed. Installation of the program will change the areal distribution of soil-cover complexes and infiltration condition classes. These changes will be accomplished by conversions in land use that change the soil-cover complex, and by applying improved land management practices on lands remaining in the same type of use.

On open areas, land conversions and treatments prescribed in the recommended program were used as a basis for determining the new areal distribution of soil-cover complexes.

On open land area programmed for conversion to forest, the present pasture, hay, or idle land-cover complex will be changed to a woodland-cover complex in approximately 25 years[1/]. In computation of future runoff this area will have a good woodland infiltration rate.

Infiltration conditions in woodland areas will be improved by the application of the recommended woodland management practices. Installation of these measures and practices will maintain good hydrologic conditions wherever they now exist and will improve the presently classified poor conditions. For example, the presently grazed woodland has the lowest infiltration rate of any forest land. Elimination of grazing will stop the soil compaction and improve the poor

1/ Bulletin 53, Yale School of Forestry, Lutz and Hawley.

forest floor conditions responsible for this low infiltration rate. A new infiltration condition having a higher infiltration rate will result in a relatively short time.

The almost complete elimination of clear cutting as a method of harvest cutting will result in maintaining much better site protection and stop the periodic deterioration of forest floor conditions responsible for the low infiltration rates on much of the forest area. Studies in comparable stands adjacent to the watershed indicate that substantial improvement in forest floor and woodland soil conditions will be attained in about 15 years.[2/]

METHODS OF APPRAISING DAMAGE

Two general types of flood damages were considered: direct and indirect. Direct damage from flood water included loss of or damage to properties and goods, the cost of moving goods or equipment, and the cost of cleaning up after floods. Indirect damage included all other losses or costs that were not counted as direct damage. These included such items as loss of business, wages, or rentals; added cost of conducting business; and cost of rerouting highway and railroad traffic.

Five classes of direct and indirect damage were recognized: agricultural, urban, industrial, highway, and railroad.

Damage from sedimentation included silting of reservoirs and road ditches, and erosion of stream banks. Other kinds of sedimentation damage were included with flood-water damages under the classes already outlined.

Fish and game damages--both direct and indirect--that result from flood waters and sedimentation were determined in a separate study.

Except for fish and wildlife, the determination of flood and sedimentation damages was based largely on data obtained from previous surveys by the U.S.Corps of Engineers.

2/ Bulletin 23, Harvard Forest. Lutz and Cline

Data on direct losses within the Engineers' damage zones were available from these surveys. Indirect damages were estimated as a ratio of indirect to direct flood losses. These ratios were calculated as follows: agricultural 0.2, urban 0.5, industrial 1.0, and transportation systems 1.0. For areas outside the Engineers' damage zones, the following ratios were developed: agricultural 0.2, urban 0.4, industrial 1.0, and transportation systems 0.5.

All damage figures are based on 1949 values (table 6).

FLOOD-WATER DAMAGE

The total average annual direct and indirect damages within zones established by the Corps of Engineers were taken directly from their reports and 1947 revisions. These damage zones include the entire main stem of the Connecticut River and portions of 17 tributaries (fig. 2).

Watershed areas outside these damage zones were subdivided into five groups: (1) Lower Connecticut tributaries from the Farmington and Scantic Rivers to the mouth; (2) Upper Connecticut River watershed tributaries (Passumpsic, Stevens, Ammonoosuc, Wells, Waits, White, Mascoma, Ottauquechee, Sugar, Black Saxtons); (3) Millers, Deerfield, Chicopee, Westfield, West, and Ashuelot Rivers; (4) Upper Ammonoosuc, Israel, Ompompanoosuc, and Williams Rivers; and (5) miscellaneous drainages.

The method of appraising total average annual damages varies by drainages largely because of differences in the available data. The methods used in each of the five watershed areas are outlined below. These methods were used to appraise direct damage; indirect damages were computed by the use of ratios as already described.

Lower Connecticut Tributaries

In appraising nonagricultural damages the floods of March 1936 and September 1938 were used as bases for estimated annual flood losses. Data supplied by the Corps of Engineers were supplemented by data gathered in a survey of areas outside the Engineers' damage zones. In this way rather complete data were compiled for the September 1938 flood. For the March 1936 flood, damages were determined

Table 6.--Estimates[1] of average annual damage

Kind of damage	Total damage	Amount Corps of Engineers program will reduce[2]	Amount subject to control by USDA program
Floodwater damage by subwatersheds:			
Connecticut River[3]	$ 45,500	$ --	$ 45,500
Connecticut River[4]	3,342,000	2,652,400	689,600
Upper Ammonoosuc	5,000	--	5,000
Israel	1,600	--	1,600
Passumpsic	111,100	--	111,100
Stevens	13,300	--	13,300
Ammonoosuc	126,300	--	126,300
Wells	48,900	--	48,900
Waits	1,600	--	1,600
Ompompanoosuc	22,200	--	22,200
White	128,500	--	128,500
Mascoma	53,700	--	53,700
Ottauquechee	64,900	--	64,900
Sugar	47,400	--	47,400
Black	149,800	--	149,800
Williams	33,300	--	33,300
Saxtons	4,400	--	4,400
West	51,600	38,800	12,800
Ashuelot	237,300	60,000	177,300
Millers	237,300	137,100	100,200
Deerfield	278,400	--	278,400
Chicopee	348,200	62,300	285,900
Westfield	249,500	53,600	195,900
Scantic	28,700	--	28,700
Farmington	119,000	5,800	113,200
Park	17,700	--	17,700
Hockanum	85,700	--	85,700
Mattabesset	15,500	--	15,500
Salmon	16,400	--	16,400
Eight Mile	19,900	--	19,900
Miscellaneous	258,700	--	258,700
Total	$6,163,400	$3,010,000	$3,153,400
Other damages:			
Gullying	1,400	--	1,400
Sedimentation	68,900	--	68,900
Stream-bank erosion	52,000	--	52,000
Total, all damages	$6,285,700	$3,010,000	$3,275,700

1/ 1949 values.

2/ Includes only existing or approved projects (8 reservoirs, 9 protective works).

3/ Above Fifteen Mile Falls.

4/ From Fifteen Mile Falls to mouth (U. S. Army Engineers' zones C-1 to C-10).

from the relationship of flood-water discharges to resulting damages; this general relationship was developed for rivers on which fairly complete damage records were available. Curves showing the relation of damage to discharge for the September 1938 and March 1936 floods were prepared for each of the eight tributaries of the lower Connecticut. From discharge-damage and discharge-frequency curves, damage-frequency curves were prepared; these were used to obtain average nonagricultural damage estimates for each tributary.

In appraising agricultural damages three classifications were used: (1) crop damage, (2) land damage, (3) damage to buildings, improvements, farm machinery, and stored crops or feed. Damages in each of these classes were appraised as follows:

1. To arrive at an estimate of crop damage, we first determined for each damage zone the area of alluvial soils and the percentage of alluvial area covered by floods of different frequencies.

   From aerial photographs the distribution of land use on alluvial soils was determined. Crop damage per acre, by months, was determined from 1949 crop values and production costs; these were weighted by probable chance of flood occurrence, by months. Total crop damage for a given flood frequency was calculated from the crop acreages flooded and the weighted crop values.

2. Damage to land was considered to include damage by scouring, sedimentation, and the resulting reduction in crop yields. Per-acre values of damage to various classes of cropland were calculated from data gathered on the Farmington River. These per-acre values were multiplied by the total area damaged, and then were related to frequency of floods.

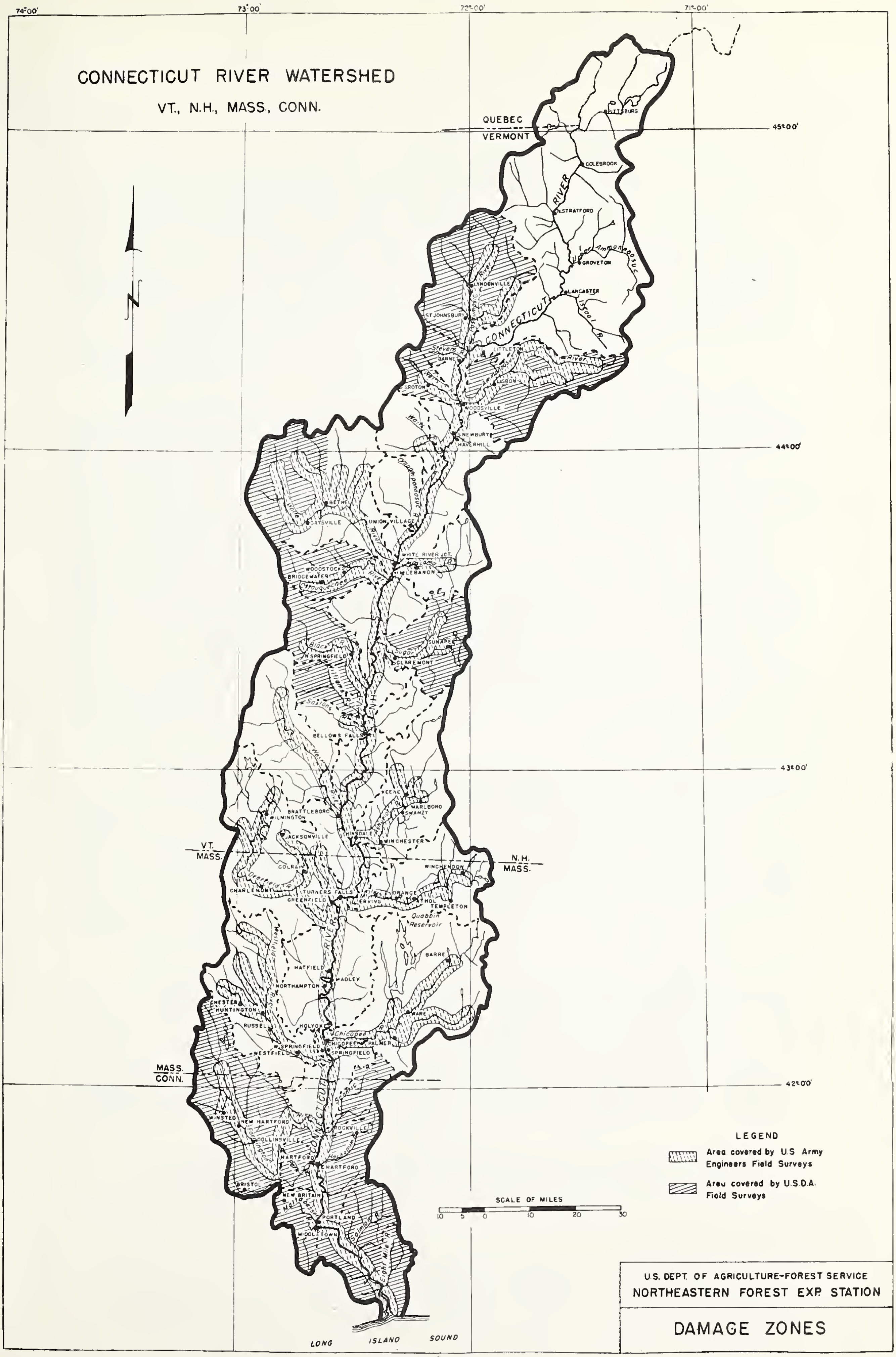
3. Estimates of damage to buildings, improvements, and stored crops were also based on Farmington River data. Total damages were calculated for floods of different frequencies in the same manner as crop and land damages.

Values for the three classes of agricultural damage were added for each of three flood frequencies, and a discharge-damage curve was prepared for each zone. From this relation and the resulting damage-frequency relation, average annual agricultural damages were calculated.

Upper Connecticut Tributaries

Through a grid system of sampling, the damages outside the Engineers' damage zones were appraised on nine watersheds above Bellows Falls. This work was done prior to September 1941.

Figure 2


CONNECTICUT RIVER WATERSHED
VT., N.H., MASS., CONN.
QUEBEC
VERMONT
VT.
MASS.
N.H.
MASS.
MASS.
CONN.
LONG ISLAND SOUND
LEGEND
Area covered by U.S Army Engineers Field Surveys
Area covered by U.S.D.A. Field Surveys
SCALE OF MILES
U.S. DEPT. OF AGRICULTURE-FOREST SERVICE
NORTHEASTERN FOREST EXP. STATION
DAMAGE ZONES

In considering eight of these watersheds (one being omitted because of a discrepancy in area covered) it was found that the average annual damages outside the Engineers' zones amounted to 44 percent of the damages inside the zones as reported by the Engineers in their 1944 Review Report on the Connecticut River. To get the total average annual damages for the whole area, the Engineers' damage figures were therefore increased 44 percent. This was done for each of the 11 tributaries listed in this group.

Millers, Deerfield, Chicopee, Westfield, West, and Ashuelot Rivers.--Following the 1938 flood, the Massachusetts State Development Commission hired the engineering firm of Moore & Haller to make a survey and report of the flood damages. From a rather comprehensive analysis of this report a ratio of damages outside the Corps of Engineers' damage zone to those within the damage zone was obtained for the Millers, Chicopee, Deerfield, and Westfield rivers. These ratios were then applied to Engineer figures for total average annual damages, exclusive of property depreciation. Because of a similarity in the drainages, the ratio for the Deerfield was applied to the West River in Vermont, and the ratio for the Chicopee was applied to the Ashuelot River in New Hampshire.

Upper Ammonoosuc, Israel, Ompompanoosuc, and Willaims Rivers.--Average annual damages for these watersheds were estimated on the basis of field sampling by Department of Agriculture survey parties. This sampling was done prior to 1942. From the data gathered, damage-frequency curves were constructed, and average annual damages were computed directly from these curves.

Miscellaneous drainages.--On some miscellaneous drainages no surveys were made, either by the Corps of Engineers or the Department of Agriculture. For these, average annual damages were estimated from data for other areas that have similar flood and damage probabilities. The average annual damages were based on the average annual damages per square mile of the comparable drainage.

Calculation of damage by classes.--Average annual direct damages were broken down into classes of damage as follows:

> From Corps of Engineers' damage figures and flood-frequency records, a composite damage-frequency curve was drawn for each class of damage; this was done for the

main stem of the Connecticut and for its tributaries. From these curves, average annual damages were calculated by classes, and these were reduced to percentages of the total average annual damage. By applying the percentage figures to the total average annual direct damages for the entire Connecticut River watershed, average annual direct damages were estimated by class of damage.

FISH AND WILDLIFE DAMAGE

Because recreational facilities--and hunting and fishing are at the top of the list--are of major importance to the economy of the Connecticut watershed, a separate survey was made to determine the effect of floods on fish and wildlife. This is the first flood-control survey in which this aspect of the problem has been considered in detail.

Appraisals of damages to fish and wildlife were based on their estimated population and the percentage destroyed annually by floods and sedimentation.

The total fish population in the watershed is estimated at 11 million game and pan fish. Five percent of this population is assumed to be lost annually because of floods and sedimentation. This represents an estimated loss of $374,800. Of this total amount 25 percent, or $93,700, is classed as direct damage. Direct damage results from excessive force of stream currents, grinding action from rocks and gravel, washing of fish downstream into uninhabitable waters, stranding of fish in temporary pools, and smothering of eggs and young fish with silt.

Indirect damages were considered to be three times the value of direct damage. They amount to $281,100 annually and result from adverse environmental conditions. These include reduced supplies of food, reduced fertility of stream and lake bottoms, fewer protective pools, fewer spawning grounds, reduced oxygen supplies, higher water temperature in summer, and pollution.

The total game population in the watershed is estimated to be 974,000 furbearers and game animals having a commercial or recreational value of $2,948,800. An estimated 2 percent of this number, having a value of $59,000, are lost annually to floods and sedimentation. Twenty-five percent of this

amount, or $14,800, is classed as a direct damage. Included as direct damages are the drowning of young and adult game and the covering of inhabited burrows and nests with silt. Indirect damages were taken as three times the direct damages. They amount to an estimated $44,200 annually, and include reduced supplies of food, loss of nesting areas, and lowered quality of range for game animals.

In view of the many intangible factors entering into the determination of fish and wildlife damages, the above figures were not included in the summary of damages in table 6.

DAMAGE FROM GULLYING

Damage from gullying is relatively slight in the Connecticut watershed. From a survey of sample farms, it was estimated that 10 acres of agricultural land are destroyed annually in the watershed by gullying. This damage amounts to $1,100 annually, and it was included as a direct damage.

In addition, it is estimated that land adjoining gullies depreciates in value, and also causes higher costs in farm operation and maintenance. This indirect damage is estimated to affect 5 acres of land per year in the watershed, and to cost $300 annually.

Gullying also occurs in woodlands, particularly along old skid and haul roads which have not revegetated. Land damages resulting from woodland gullying were not evaluated in monetary terms pending the development of reasonable methods of evaluation.

SEDIMENTATION DAMAGE

Two types of sedimentation damages were considered: (1) silting of road ditches and culverts, and (2) sedimentation of reservoirs. An estimate of increased annual costs of highway maintenance per mile of State and town roads due to washing of soil from adjoining lands was obtained from State Highway departments. Applying this cost per mile to the total road mileage within the watershed provided a total annual damage figure of $68,900.

Sedimentation damage is relatively minor in the reservoirs of the watershed. While sedimentation damages were investigated at 63 reservoirs it was found that only nine were considered likely to suffer measurable damages, when an annual sedimentation rate of 0.15 acre-feet per square mile was used. Detailed investigations at these nine reservoirs indicated an average annual damage of only $400.

STREAM-BANK EROSION DAMAGES

Stream-bank erosion is a serious problem in the New Hampshire-Vermont portion of the watershed. A field reconnaissance was made to obtain a basis for estimating the extent of stream-bank erosion and land damage resulting from it.

This survey covered the main river from the Massachusetts-Connecticut State line to Wilder, Vermont, and the White River and its tributaries in Vermont. The length of eroding stream bank was estimated for three height-of-bank classes, for three degrees of erosion, and by major land-use classes. A rate of bank cutting was determined for actively eroding banks by field observations, supplemented by inquiry of local landowners. It was estimated that the length of eroded stream banks would about double during the next 50 years if present rates of erosion continued.

The ratio between length of eroding stream bank and total stream mileage was determined separately for the main river and for the White River and its tributaries. These ratios were applied to the stream mileages in table 7 to determine the total length of actively eroding stream bank in the watershed.

The average annual loss of land was determined in acres for each major land-use class in accordance with the observed rates of bank cutting. Present value of the land was determined from local residents and increased by 50 percent to allow for depreciation in value of the remaining area. On this basis the value of land lost each year through stream-bank erosion was estimated at $52,000. Damage along the main river was $34,000 and on the tributaries $18,000.

It is recognized that other damages result from stream-bank erosion. Included among them are: destruction of fish and their habitat by sediment, erosion of highway and

bridge approaches, deposition of infertile material on farmlands, channel aggradation, increased water treatment costs, and many others. These damages have been included as floodwater and sedimentation damages.

Table 7.--Summary of extent of stream-bank erosion

State and stream	Length of stream 1/	Estimated length of eroding stream bank
	Miles	Miles
Connecticut:		
Connecticut River	71	10
Major tributaries	188	5
Minor tributaries	1,200	180
Total	1,459	195
Massachusetts:		
Connecticut River	64	16
Major tributaries	358	9
Minor tributaries	2,100	310
Total	2,522	335
Vermont:		
Connecticut River	235	26
Major tributaries	522	51
Minor tributaries	3,200	600
Total	3,957	677
New Hampshire:		
Connecticut River	235 2/	30
Major tributaries 3/	432	25
Minor tributaries	2,400	480
Total	3,067	535
All States:		
Connecticut River	370	82
Major tributaries	1,500	90
Minor tributaries	8,900	1,570
Total for watershed	10,770	1,742

1/ Length of stream used as a basis for estimating stream-bank erosion.

2/ Not included in total for watershed since it is included in figure for Vermont.

3/ Includes 23 miles of Connecticut River entirely in New Hampshire.

PROGRAM

Needs of the Watershed

A watershed survey was made to determine total needs of the watershed. In general, survey personnel investigated the following factors: (1) present use of watershed land, (2) present land-management practices, (3) present condition of land and its effectiveness for controlling runoff and preventing soil erosion, (4) areas where changes in land use were needed to correlate use with land capability, (5) areas needing improved land-management measures and practices to build up or maintain optimum watershed protection conditions, and (6) number and extent of related structures and measures needed to supplement the land conversion and treatment program.

These data were used to prepare a summary of the total needs of the watershed for waterflow retardation and erosion control. In the main, these needs included land-use conversions (table 8), improved land-management measures and practices, and structural installations to correct unsatisfactory watershed-protection conditions (table 9).

ACCOMPLISHMENTS OF CURRENT PROGRAM

Several land management programs contributing to flood control objectives are currently being carried on by various Federal and state agencies. The Department of Agriculture agencies engaged in this work are: Production and Marketing Administration; Extension Service; Soil Conservation Service; and the Forest Service. These agencies participate in current programs as follows: the Production and Marketing Administration assists landowners to carry out conservation practices by making direct contributions of a portion of the cost; Extension Service cooperates with state extension service in conducting educational programs aimed at increasing the application of many of the needed measures and practices; Soil Conservation Service is furnishing technical assistance to soil conservation districts for planning and installing soil and water conservation measures; Forest Service, as provided by the Clarke-McNary and Norris-Doxey laws, cooperates with the states in improving fire protection, in producing seedlings for reforestation, and in establishing sound forestry practices.

Table 8.--Present land use and proposed changes under a watershed improvement program, in acres.

Present land use		Proposed future land use										Proposed net change in land use
Cover	Area	Clean-tilled	Rotation hay	Long-term hay	Pasture, lightly grazed	Idle	Other	Grazed farm woodland	Ungrazed farm woodland	Forest	Urban, road, and water	
Open farm land:												
Clean-tilled	106,000	101,000	--	3,100	1,300	--	--	--	600	--	--	- 5,000
Rotation hay	653,000	--	553,300	62,800	26,600	--	--	--	10,300	--	--	- 79,000
Hayland	110,000	--	9,300	96,700	3,100	--	--	--	900	--	--	+ 55,000
Pasture	675,000	--	4,500	2,100	471,000	--	--	--	197,400	--	--	-151,000
Idle	30,000	--	6,700	300	400	5,000	--	--	17,600	--	--	- 25,000
Other	96,000	--	--	--	--	--	96,000	--	--	--	--	0
All open farm land	1,670,000	--	--	--	--	--	--	--	--	--	--	-205,000
Forest:												
Grazed farm woodland	807,000	--	--	--	21,600	--	--	26,500	758,900	--	--	-780,000
Ungrazed farm woodland	910,000	--	200	--	--	--	--	500	909,300	--	--	+985,000
Nonfarm forest	3,063,000	--	--	--	--	--	--	--	--	3,063,000	--	0
All forest	4,780,000	--	--	--	--	--	--	--	--	--	--	+205,000
Urban, road, and water	685,000	--	--	--	--	--	--	--	--	--	685,000	0
Total	7,135,000	101,000	574,000	165,000	524,000	5,000	96,000	27,000	1,895,000	3,063,000	685,000	0

Table 9.--Summary of total needs of the watershed for water-flow retardation and erosion prevention

Measure	Unit	Total needs
Improved forest management	Acres	4,935,000
Acquisition of forest land	Acres	154,000
Establishment of forest cover	Acres	146,900
Contour strip cropping	Acres	471,200
Cover crops	Acres	106,000
Crop rotations	Acres	56,000
Crop residue management	Acres	31,500
Establish perennial hay	Acres	65,900
Field diversions and terraces	Miles	1,940
Outlets and watercourses	Lin. Ft.	3,643,200
Structures	Each	2,900
Pasture management	Acres	239,400
Pasture contour furrows	Acres	43,700
Stream bank stabilization	Miles	1,742
Stream channel improvement	Miles	480

The accomplishments of current programs of these agencies were determined from a study of records of actual accomplishment over the past three years. Information collected from this study was summarized, discussed with local representatives of the agencies and served as a basis for determining accomplishments by measures for an average year. The average annual accomplishments thus determined were extended over the proposed installation period on the assumption that they would be continued at current rates. Total accomplishments of current programs were deducted from total watershed needs to determine the portion of total needs to be accomplished by the recommended program.

RECOMMENDED PROGRAM

The recommended program includes the intensification, adaptation, and acceleration of those portions of current programs of the Department deemed of primary importance to the objectives of the Flood Control Act plus the additional measures, practices, and structures needed to complete a basic system of water-flow retardation and erosion prevention.

In broad outline, the recommended program proposes changes in land use and improvements in management practices and measures. In addition to soil- and land-management measures the program includes measures to stabilize stream banks, control mountain torrents, and correct critical channel conditions. A summary of the measures is presented in table 10.

When changes in land use or management were considered, heavy weight was given to the hydrologic effectiveness of each; the probable effects on the economy of the watershed and on individual landowners were also considered. In general, studies indicate that most of the benefits--both hydrologic and economic--will be obtained from the following measures: (1) elimination of grazing on forest land and overgrazing in open pasture; (2) conversion of "poor" forest cover to "good"; and (3) improvement in open land (crop land) practices.

A brief discussion of the individual measures to be installed on forest and open land by the recommended program follows:

Table 10.--Summary of measures to be accomplished by the recommended program

Measure	Scheduled for accomplishment by recommended program
Improved forest management	4,985,000 acres
Acquisition of forest land	154,000 acres
Establishment of forest cover	138,560 acres
Contour strip cropping	471,200 acres
Cover crops	67,900 acres
Crop rotations	20,400 acres
Crop residue management	23,800 acres
Establish perennial hay	25,700 acres
Field diversions and terraces	1,648 miles
Outlets and watercourses	2,649,200 lin. ft.
Structures	1,151 each
Pasture management	151,000 acres
Pasture contour furrows	43,700 acres
Stream bank stabilization	1,662 miles
Stream channel improvement	480 miles

Forest Area

Three general measures are proposed for forested areas: (1) furnishing woodland owners with technical services and advice to improve management practices and to achieve the objective of maintaining a thrifty, well-stocked forest cover on the land to increase the infiltration and soil moisture storage capacity of forest soils, (2) conversion of improperly used crop, pasture, hay and idle lands to forest cover in accordance with capability to reduce runoff and control erosion; (3) public acquisition of watershed lands to insure the treatment and continuity of management needed to build up and maintain optimum woodland hydrologic conditions in critical headwater areas.

Improved Forest Management

From a hydrologic standpoint, three characteristics of forest soil can be modified by management. They are depth of soil, amount of organic matter in the soil profile, and the type and depth of the humus layer. Program measures were selected which would accomplish the following objectives: (1) increase the depth of shallow soils by improving the type and depth of humus and increasing the amount of organic matter in the soil, thereby increasing the soil moisture storage capacity of the soil profile; (2) improve the infiltration condition of all forest soils by improving the type and depth of humus; (3) prevent the formation of impermeable frost in all forest soil profiles by developing protective layers of humus and litter.

The measure recommended for improving hydrologic conditions in forest areas is essentially one of improving forest management by furnishing technical services to the owners of 4,211,000 acres of forest land. Management plans, pointing out the operations needed to achieve objectives, will be prepared for about 50,000 individual owners. Timber marking service will provide for harvest cuts on all land to insure maintenance of a protective cover. Additional technical services are needed to outline cultural operations on shallow soil areas that are major sources of rapid surface runoff during storm periods. Special attention will be given to these areas in order to develop a cover composed primarily of species that are effective in building up humus

depth and increasing the amount of organic matter in the soil profile. In this watershed there appears to be no other feasible way of increasing the soil moisture storage capacity of shallow soils.

Technical service will include advice and assistance in carrying on logging operations with minimum disturbance of the forest floor. Advice will be given on how to locate and construct future logging roads to avoid concentration of runoff and accelerated erosion and on practices needed to correct the unsatisfactory conditions on existing roads. Many previously logged areas are interlaced with abandoned logging roads and trails which are now active drainage ways serving to concentrate both surface and subsurface runoff. This concentrated runoff contributes directly to flood peaks and is responsible for most of the erosion in woodland areas. Water spreading devices, gully checks, outlets and diversions will be installed to correct these conditions on all forest land.

Management of forest land in accordance with the technical recommendations for improving hydrologic conditions will result in improvement in timber quality and quantity. Technical service will be provided to assist in the marketing and utilization of the improved products in order that landowners may realize full financial benefits from installing and maintaining the recommended practices.

About 612,000 acres of the farm woodland are currently grazed by livestock. This activity reduces the efficiency of the other forest management practices and will be discontinued. Livestock grazing will be excluded from about 585,000 acres of the presently grazed forest land and from the 194,000 acres of open land scheduled for conversion to forest. Grazing exclusion will in general be accomplished by fencing. It is estimated that approximately 2,000,000 rods of fencing will be required.

Establishment of a Forest Cover

Approximately 194,000 acres of open land will be converted to forest. Field surveys indicate that approximately 139,000 acres will have to be planted and the remainder will restock naturally with desirable species from adjacent seed sources. Planting offers the quickest and most effective way of securing optimum hydrologic conditions on these areas.

Soil erosion will be reduced and infiltration rates substantially increased within 10-15 years. The forest area of the watershed will increase to 4,985,000 acres as a result of this measure.

Land Acquisition

Public acquisition of approximately 154,000 acres of forest land is recommended. The land recommended for purchase is vital for watershed protection purposes, is in poor condition because of past use, and contributes materially to flood problems. In general it is rough, steep, stony land located on the upper slopes and ridges in headwater areas. Normally well forested, these lands have been so abused that they need major rehabilitation to restore the cover for effective runoff and sediment control. Productivity is low and the land will return no income for many years. Acquisition will be undertaken only if it is clear that it is not economically feasible for the present owner to install the needed rehabilitational measures during the proposed installation period. Land located within the present national forest purchase boundaries will be acquired with Federal funds. Land outside of these boundaries will, in all probability, be purchased by state or other local agencies and maintained as a part of existing or now public forests, game reserves and parks.

Approximately 45,000 acres of land inside present national forest boundaries should be acquired to insure correction of unsatisfactory watershed conditions. Of this total about 3,300 acres is located in the White National forest in New Hampshire and 41,250 acres in the Green Mountain National forest in Vermont.

An additional 109,100 acres of critical watershed land, located outside of national forest boundaries, should be acquired as follows: New Hampshire, 10,200 acres; Vermont, 20,000 acres: Massachusetts, 40,000 acres; and Connecticut, 38,900 acres.

Maintenance of Management Program

Maintenance costs include supervision, inspection, and technical assistance to ensure that the management plan is

followed and that operations are kept up to standard. Services to landowners and processors, such as in marketing and utilization, will be maintained to ensure continued cooperation with timber- and watershed-management plans.

Plans developed will occasionally have to be revised to fit the needs of the landowners. Where changes in ownership take place, new owners will be informed and instructed in the program and management plan. It is only through continuation of the measures that the initial investment in the management program will be protected and that dividends will accrue in the form of flood-control benefits and water conservation.

Open Land

The needed improvement measures for open farm land are designed basically to reduce erosion and runoff to a minimum.

Proper application of these measures requires that land-use capability classes be recognized. Factors that determine capability are steepness of slope, soil texture and depth, stoniness, drainage, and erosion conditions. Thus, under some soil conditions, the maximum slope for rotation crops may be 10 percent; but under other more favorable soil conditions the maximum slope for crops may safely reach 20 percent. Similarly, woodland might be recommended for all slopes over 25 percent where soil conditions make long-term hay or pasture production impractical. In most instances slopes of 35 percent or over are recommended for woodland regardless of soil conditions. The decisions on which lands shall be retired to less intensive farm uses are further influenced by location or accessibility of the land, and by various economic factors.

Improved land management involves the betterment of vegetative cover, the adoption of improved methods of tillage, and the installation of water-disposal systems to take care of excess runoff. In some cases the installation of mechanical barriers is necessary to arrest erosion while the land-treatment program is in the process of becoming effective.

In computing the total needs of the watershed, not only were these general objectives considered, but also the economic ability of the area to support the installations and to maintain them.

Land Conversion

The objective of changes in land use is to adjust these farm land uses--crop, pasture, and woods--in accordance with land-use capability. Only by such adjustments will the greatest possible flood-control benefits be realized.

Cropland.--Within the watershed there are certain areas of cropland, located on the steeper slopes, that are eroding and are contributing to flood and sedimentation damage. Their conversion to less intensive uses, such as hay, pasture, or woodland is recommended. Likewise, small areas of hay land, pasture, and woods more suitable for the production of crops are recommended for conversion to cropland. The net result of all these changes will be a reduction in crop-land area. In spite of this reduction the yield through improved farm practices should be greater in the future than at present.

Pasture.--There will also be a reduction in pasture area, largely from the conversion of steep mountain pasture to woodland. However, the improvement and management of permanent pastures will permit the carrying of more stock than is carried on present pasture area.

Land Treatment

Cropland.--With the proposed changes in land use, 840,000 acres will be used for the production of crops, including 165,000 acres of long-term hay, 524,000 acres of rotation hay, and 101,000 acres of clean-tilled crops; and approximately 524,000 for permanent pasture.

This area of open land, total 1,364,000 acres, can be maintained in such use indefinitely if properly treated and managed with conservation methods.

The principal land-treatment measures needed to correct unsatisfactory watershed conditions on open land are shown in table 9. They include such items as:

1. Construction of approximately 1,650 miles of diversions and terraces to intercept and divert surface runoff and reduce sediment.

2. Installation of approximately 500 miles of waterways by shaping and establishing vegetation to provide suitable outlets for the disposal of concentrated surface runoff from fields and small subwatersheds.

3. Construction of approximately 1,150 stabilizing and sediment-control structures in waterways to stabilize channels, arrest gully development, and control sediment.

4. Construction of approximately 17,400 miles of contour furrows on about 43,700 acres of pasture land to reduce surface runoff.

5. Establishment of approximately 25,700 acres of perennial hay; and installation of other soil- and water-conservation practices, such as strip cropping, contour cultivation, crop rotations, cover crops, crop-residue management, pasture management, and related items to be applied in proper combination with measures listed above, to complete a basic system of soil and water conservation in accordance with the needs and capabilities of the land of the watershed to retard runoff, reduce soil erosion, and maintain soil resources.

Maintenance

Maintenance will be needed to ensure continued hydrologic benefits from the program for open farm land. It is expected that private landowners will adopt the land-treatment program as a part of their regular farm operations.

Stream-bank Stabilization

Continued misuse and poor management of lands over a long period have seriously upset stream behavior. This has resulted in deterioration and damage to stream banks that cannot, in many cases, be rectified by land-use changes and treatment alone. Special measures are needed to control further impairment of stream banks. It is estimated that approximately 1,662 miles of stream banks need treatment. About 90 percent of this mileage is on minor tributary streams. The necessary control measures will be applied as a part of the land management program.

The control measures to be used shall vary in design to fit specific cases. In instances where bank erosion is critical, measures such as bank sloping and protection by cribbing or rip-rap may provide the only sure control. In other instances it may be possible to utilize a combination of physical and vegetative devices. When a combination is used it will probably consist of (1) bank sloping, (2) stabilization from toe of slope to point on the bank affected by annual high water, and (3) planting of the upper slope to low-growing, woody vegetation. No attempt is made here to limit the type of control or to designate locations where such work should be carried out. These will have to be planned at the time of initiation of an action program.

Maintenance of installed control measures is required. This will involve elimination of grazing on stream banks and of cultivating fields too close to the banks. Where vegetative controls are used the woody plants should be pruned and thinned at intervals to prevent development of large trees or the formation of large clumps that would otherwise impede the flow of water.

Testing Program Effectiveness

In order that the effectiveness of the flood-control program may be calculated, it is recommended that several hydrologic stations be established and maintained. These are provided for in the estimated costs of the program. These stations should be installed on small watersheds representative of the general land-use conditions to be improved. To keep the work of analysis and evaluation within reasonable bounds, the size of the study watershed should be small. Measurements to be made would include stream flow, precipitation, soil moisture, vegetative cover changes, soil structure, and other factors influenced by the program.

The stations should be installed as soon as possible after funds are made available for an action program. They should include a complete set of measuring devices such as weirs, stream gages, rain gages, soil wells, and other means needed for complete hydrologic analyses. At the time of installation a complete cover, soil, and geologic survey of the watershed should be made.

Maintenance will include upkeep of the station, collection of data, and analysis and interpretation of data.

Educational Assistance

The program of education and demonstration, carried on principally by the Extension Service, will need intensification if the planned land-treatment measures and practices are to be installed. The present organization will be supplemented by the employment of technical specialists and facilitating personnel in the fields of forestry, agronomy, and farm management. Activities of the additional personnel will be confined primarily to the areas where recommended action programs are under way or will be initiated within a reasonable period of time.

Additional Measures

Surveys of the watershed indicated that all of the unsatisfactory watershed conditions would not be corrected by installation of the recommended land treatment and related measures. Additional measures are needed to complete a balanced runoff and erosion control program. It is apparent that unsatisfactory channel conditions are responsible for a substantial portion of the indicated flood damages. Steep, unstable mountain stream channels contribute excessive volumes of bedload material during storm periods. This material is deposited in downstream channels and reduces channel discharge capacity. Consequently, flood frequencies are increased on much of the agricultural flood plain. Corrective action is required to reduce the movement of bedload material from upper stream channels and to clean out presently deposited material in the lower channels.

Stream Channel Improvement

A survey of stream channel conditions indicated that corrective measures are justified on approximately 480 miles of channel. The corrective measures include (1) removal of debris and sediment deposits to increase discharge capacity of lower stream channels, (2) realignment, bank sloping, clearing and snagging wherever necessary to improve channel conditions and reduce flood frequency, and (3) stabilization of mountain stream channels to control bedload movement and reduce downstream aggradation.

COST OF RECOMMENDED FLOOD CONTROL PROGRAM

Costs of program measures and practices were determined by applying unit costs--based on 1949 prices for labor, equipment, and materials--to the number of units to be installed in the watershed. Operations records of the Soil Conservation Service, Forest Service, and other Federal and state agencies were used in determining quantities and types of measures and practices. Total costs of the program were computed on the basis that the recommended measures and practices will be installed during a 20-year period.

Total cost of installing the recommended program is estimated at $35,536,000 (table 11). Of this amount $33,734,000 is required to carry out the land treatment and associated measures and $1,802,000 is for the additional measures needed to provide a balanced watershed program. Annual operation and maintenance costs after installation are approximately $2,726,000 (table 12). Maintenance of land treatment and related measures will cost about $2,636,000 annually while maintenance of additional measures will require $90,000.

In general, public agencies will furnish technical guidance and educational and demonstrational assistance that could not be supplied otherwise. In addition, they will provide direct aids, such as conservation payments and special materials and equipment that are necessary to insure basin-wide application of program measures. The distribution of public costs between Federal and other public agencies is based on the pattern already established by current programs. Landowners will furnish labor, some equipment, necessary right of ways and materials. A summary of costs by measures and by source of funds is shown in tables 11 and 12.

FOREST LAND

The cost of the forest land phase of the program is based on a sample watershed in which ownership, soil cover, and other data were studied in detail. From these and other available data, per acre costs of the measures were estimated. These costs were extended to the total forest land needing treatment to determine total costs.

Table 11.--Cost of installing recommended program by source of funds, Connecticut River watershed (1949 prices).

Measure	Quantity and unit	Cost of installation			
		Federal	Other public	Private	Total
		(dollars)	(dollars)	(dollars)	(dollars)
Land treatment measures					
Improved forest management					
Private land	4,211,000 acres	9,100,000	1,835,000	5,428,000	16,363,000
National forest	340,000 acres	366,000	--	--	366,000
Other public land	434,000 acres	--	773,000	--	773,000
Total		9,466,000	2,608,000	5,428,000	17,502,000
Land acquisition					
National forest	45,000 acres	540,000	--	--	540,000
Other public land	109,000 acres	--	1,083,000	--	1,083,000
Total		540,000	1,083,000	--	1,623,000
Forest cover establishment	139,000 acres	1,670,000	847,000	795,000	3,312,000
Stream-bank stabilization	172 miles	2,722,000	91,000	289,000	3,102,000
Contour strip cropping	471,200 acres	946,000	35,000	201,000	1,182,000
Cover crop establishment	67,900 acres	49,000	11,000	312,000	372,000
Crop rotations	20,400 acres	13,000	1,000	--	14,000
Crop residue management	23,800 acres	11,000	1,000	--	12,000
Establish perennial hay	25,700 acres	121,000	46,000	1,410,000	1,577,000
Field diversions and terraces	1,648 miles	577,000	20,000	101,000	698,000
Outlets and watercourses	2,649,200 L. ft.	578,000	20,000	72,000	670,000
Structures	1,151	562,000	22,000	166,000	750,000
Pasture management	151,000 acres	560,000	55,000	1,603,000	2,218,000
Pasture contour furrows	43,700 acres	681,000	21,000	--	702,000
All land treatment measures		18,496,000	4,861,000	10,377,000	33,734,000
Additional measures					
Stream channel improvement	480 miles	1,162,000	400,000	240,000	1,802,000
Total installation cost[1]		19,658,000	5,261,000	10,617,000	35,536,000

[1] The cost of technical services, educational assistance, administration of direct aids, and testing and adjusting program measures is included in the above and amounts to approximately 24 percent of the total cost.

Table 12.--Annual cost of operating and maintaining recommended program by source of funds, Connecticut River watershed.

Measure	Quantity and unit	Cost of maintenance: Federal (dollars)	Other public (dollars)	Private (dollars)	Total (dollars)
Land treatment measures					
Improved forest management					
Private land	4,211,000 acres	363,000	332,000	573,000	1,268,000
Other public	434,000 acres	--	43,000	--	43,000
Total		363,000	375,000	573,000	1,311,000
Stream-bank stabilization	1462 172 miles	13,000	--	2,000	15,000
Contour strip cropping	471,200 acres	--	--	7,000	7,000
Cover crop establishment	67,900 acres	--	--	292,000	292,000
Establish perennial hay	25,700 acres	--	--	583,000	583,000
Field diversions and terraces	1,648 miles	--	--	3,000	3,000
Outlets and waterways	2,649,200 L. ft.	--	--	21,000	21,000
Pasture contour furrows	43,700 acres	--	--	129,000	129,000
Structures	1,151	--	--	3,000	3,000
Pasture management	151,000 acres	--	--	272,000	272,000
Additional measures					
Stream channel improvement	480 miles	45,000	45,000	--	90,000
		421,000	420,000	1,885,000	2,726,000

It is estimated that the total cost of installing the recommended measures and practices on forest land is $22,437,000. The annual cost of operation and maintenance is estimated at $1,311,000.

Federal costs.--Federal cost of installation is $11,676,000, annual operation and maintenance cost is $363,000.

Other public costs.--Other public cost of installation is $4,538,000, annual operation and maintenance cost is $375,000.

Private costs.--The cost to private owners for installation is $6,223,000, and for annual operation and maintenance $573,000.

OPEN LAND

Costs of the control measures were determined by applying unit costs of the measures to the amounts of measures to be installed and maintained. Materials and labor, including unpaid family labor, are part of the program cost. Technical service costs, including planning, supervising installation, and administration were computed and applied to the recommended control measures.

The total installation cost of the recommended open land measures is approximately $8,195,000. The annual cost of operation and maintenance is estimated to be $1,310,000.

Federal costs.--Federal cost of installation is estimated to be $4,098,000.

Other public costs.--Other public cost of installation is estimated to be $232,000.

Private costs.--Private cost of installation is estimated to be $3,865,000. Annual operation and maintenance cost is $1,310,000.

LAND TREATMENT MEASURES
APPLIED ON BOTH FOREST AND OPEN LAND

Stream-bank Stabilization

Installation.--Costs of the recommended land treatment program include $3,102,000 for installing supplemental measures to control stream-bank erosion. These funds are proposed for treatment of only the most critical areas contributing to the flood problem. The Federal Government will contribute $2,795,000, other public agencies $18,000, and landowners $289,000.

Maintenance.--Maintenance of the established measures for stream-bank control provided in the flood-control program will require an average annual expenditure of $15,000. The Federal Government will contribute $13,000 and private owners $2,000. Maintenance of stream-bank stabilization measures will begin after their installation.

Testing Program Effectiveness

A public expenditure of $50,000 for equipment, materials, and labor is proposed for these installations. An additional $700,000 will be needed during the installation period to operate and maintain these installations and evaluate collected data. This cost has been distributed proportionately to the land treatment measures.

Educational Assistance

Estimates of the Extension Service place the cost of intensifying extension activities during the installation period at $1,813,000. The Federal Government will pay up to 50 percent and other public agencies, state and local, 50 percent. This cost has been distributed proportionately to the land treatment measures.

ADDITIONAL MEASURES

Stream Channel Improvement

The estimated cost of the recommended stream channel improvement program is $1,802,000. Federal costs are $1,162,000, other public costs $400,000, and private individuals will contribute $240,000. Maintenance after installation will cost $90,000 annually, equally divided between Federal and other public agencies.

HYDROLOGY

To evaluate the effectiveness of each proposed land-use treatment in reducing flood runoff, certain hydrologic studies were made. Procedures were as follows:

From existing hydrologic data, the average amount and intensity of rainfall for each flood on a subwatershed was determined. From this the surface runoff was computed for each soil-cover complex. The subsurface runoff was also computed, since it contributes materially to floods. The total amount of flood runoff was checked against that computed from the flood hydrograph.

From these data of actual conditions, computations were made of the conditions under the proposed flood-control program. Runoff was computed for the soil-cover complexes (weighted by their areal distribution) that would be obtained by the program. These runoff data were analyzed to determine each land-use improvement that would produce an appreciable reduction in flood flow.

For all subwatersheds where detailed computations were not made, the reduction in flood flows was estimated by applying the runoff reductions determined for each soil-cover complex to a "design storm" (a set of theoretical storm conditions used as a basis for computations).

For the purpose of estimating benefits, reductions were computed only for those land-use improvements that were hydrologically significant. The procedures used on the Farmington River subwatershed are described in detail below, as an example.

SOURCES OF DATA

Rainfall data are collected by the U. S. Weather Bureau in cooperation with numerous public and private agencies. These data are available in Weather Bureau publications such as hydrologic bulletins and climatological data reports.

Records of stream peaks and discharges are made by the U. S. Geological Survey. These records are available in publications of the Water Resources Branch of the U. S. Geological Survey. (See figure 3 for location of rainfall- and stream-gaging stations.)

FLOODS STUDIED

A study was made of floods on the Farmington River that have been recorded at the stream-gaging station at Tarriffville, Conn. Five serious floods have occurred that were suitable for hydrologic analysis. These were on November 2-4, 1927; March 9-12, 1936; March 16-22, 1936; January 24-25, 1938; and September 18-22, 1938.

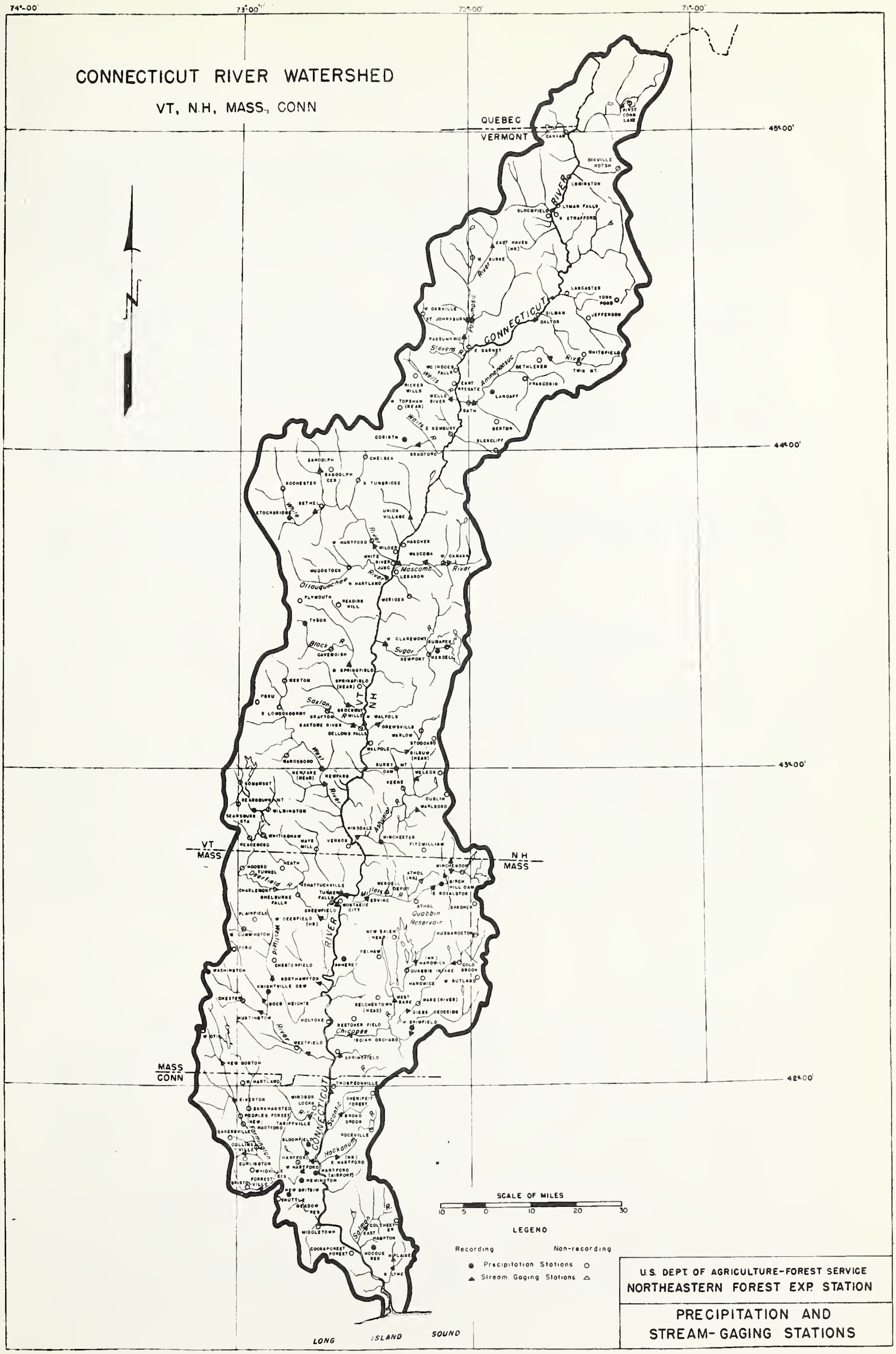
For each of these floods runoff charts--hydrographs--were constructed (figs. 4 & 5). The base flow was drawn on each hydrograph from rainfall and discharge records for before and after the flood. The volume of water runoff in inches for the watershed during the storm was obtained by measuring on the hydrograph the area above the base flow.

PRECIPITATION

Rainfall.--The average amount of rainfall in inches during the storm period was determined from an isohyetal map (figs. 6, 7, 8). The storm period was selected from the runoff hydrographs and the rainfall records. The isohyetal map was made by plotting on a map the total storm rainfall for each rainfall station, and then drawing lines through points that had equal amounts of rainfall. The average volume of rainfall was determined from the isohyetal map by Thiessens' method.

The hourly distribution of rainfall over the Farmington subwatershed was computed by prorating the hourly

Figure 3


CONNECTICUT RIVER WATERSHED
VT, N.H, MASS., CONN
QUEBEC
VERMONT
VT
MASS
N H
MASS
MASS
CONN
LONG ISLAND SOUND
SCALE OF MILES
LEGEND
Recording
Non-recording
Precipitation Stations
Stream Gaging Stations
U.S. DEPT. OF AGRICULTURE-FOREST SERVICE
NORTHEASTERN FOREST EXP. STATION
PRECIPITATION AND
STREAM-GAGING STATIONS

rainfall at Hartford, Conn., according to the ratio of the average rainfall over the watershed to the total storm rainfall at Hartford. The hourly rainfall values were separated into half-hour values; excessive precipitation intensities at Hartford were used when available.

Snow.--The water content (in inches) of snow cover on the ground at the beginning of the storm period was determined from all available sources and was plotted on the isohyetal map. Lines of equal water content of snow were interpolated on the map from the plotted points. The average water content of snow cover was determined by Thiessens' method from the snow-cover map (fig. 6).

The rate of snow melt was computed with a formula developed from a special study by the U. S. Weather Bureau on the Connecticut watershed:

$$D = KV\ (Tw - 32^{\circ}\ F)$$

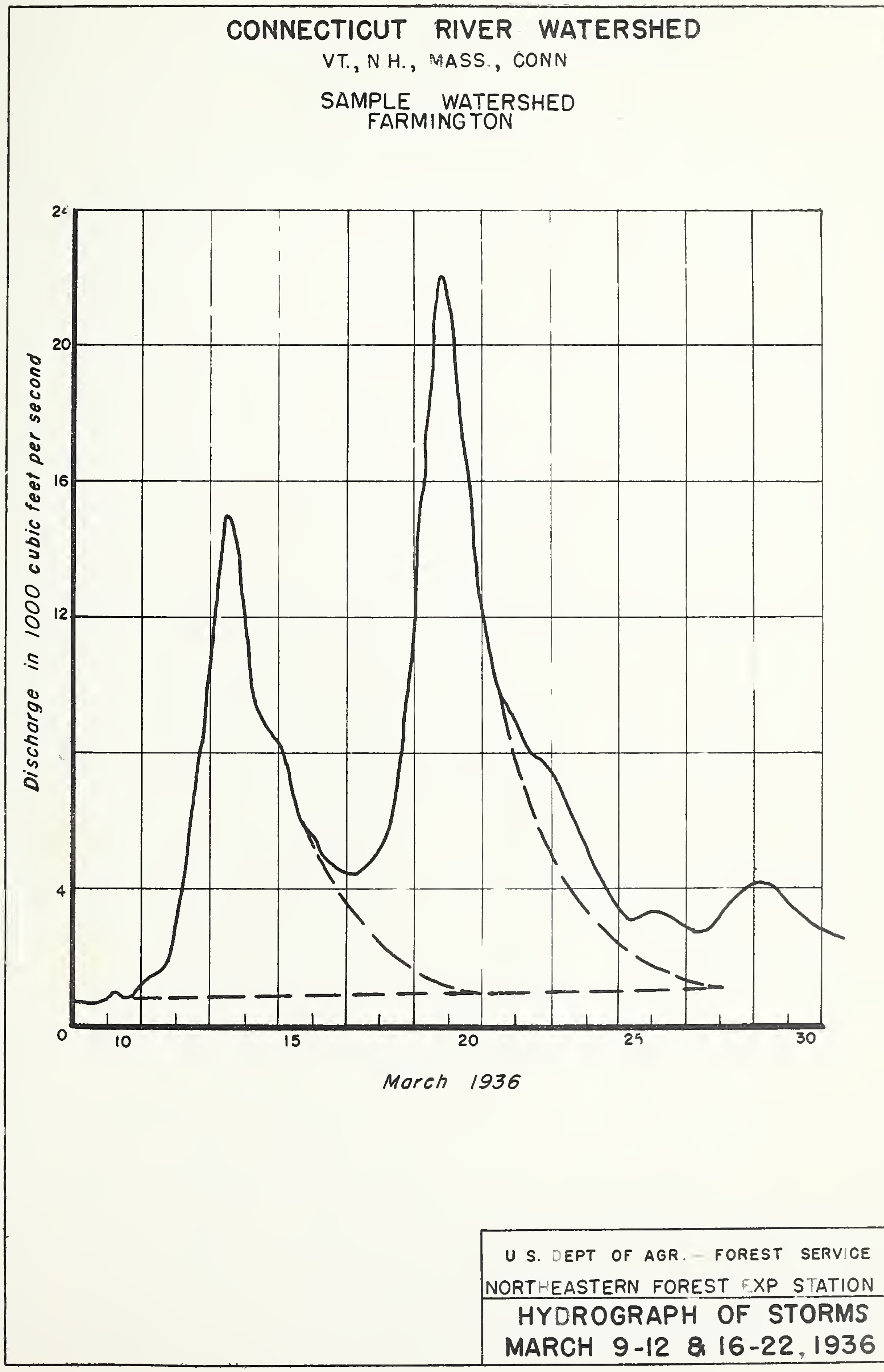
in which D = Snow melt in inches per 6 hours
V = Wind velocity in miles per hour
Tw = Wet-bulb temperature
K = Factor of melt rate to heat supplied

The snow melt was computed by using K values of 0.0050 for open areas and 0.0033 for the forested areas. The wet-bulb temperatures were obtained by adjusting the temperatures at Hartford to the mean temperature of the basin. The total snow melt was computed until either the flood ended or the snow was completely melted.

RUNOFF

Surface runoff.--Surface runoff was determined by computing the excess of rainfall above the infiltration rate of each soil-cover complex. (The infiltration rates of the soil-cover complexes were based on field infiltrometer runs.) The areal extent of each soil-cover complex was determined by the land-use survey (tables 13 and 14). In making the surface runoff computations, the rainfall intensities were listed chronologically by hourly or half-hourly values if they exceeded the lowest infiltration rate, and by 4-hour values if they did not. The rainfall excess for each soil-cover complex was added and weighted by the ratio of the area of the soil-cover complex to the

Figure 4



CONNECTICUT RIVER WATERSHED
VT., N.H., MASS., CONN
SAMPLE WATERSHED
FARMINGTON
Discharge in 1000 cubic feet per second
0
4
12
16
20
24
10
15
20
25
30
March 1936
U S. DEPT OF AGR. — FOREST SERVICE
NORTHEASTERN FOREST EXP STATION
HYDROGRAPH OF STORMS
MARCH 9-12 & 16-22, 1936

Figure 5

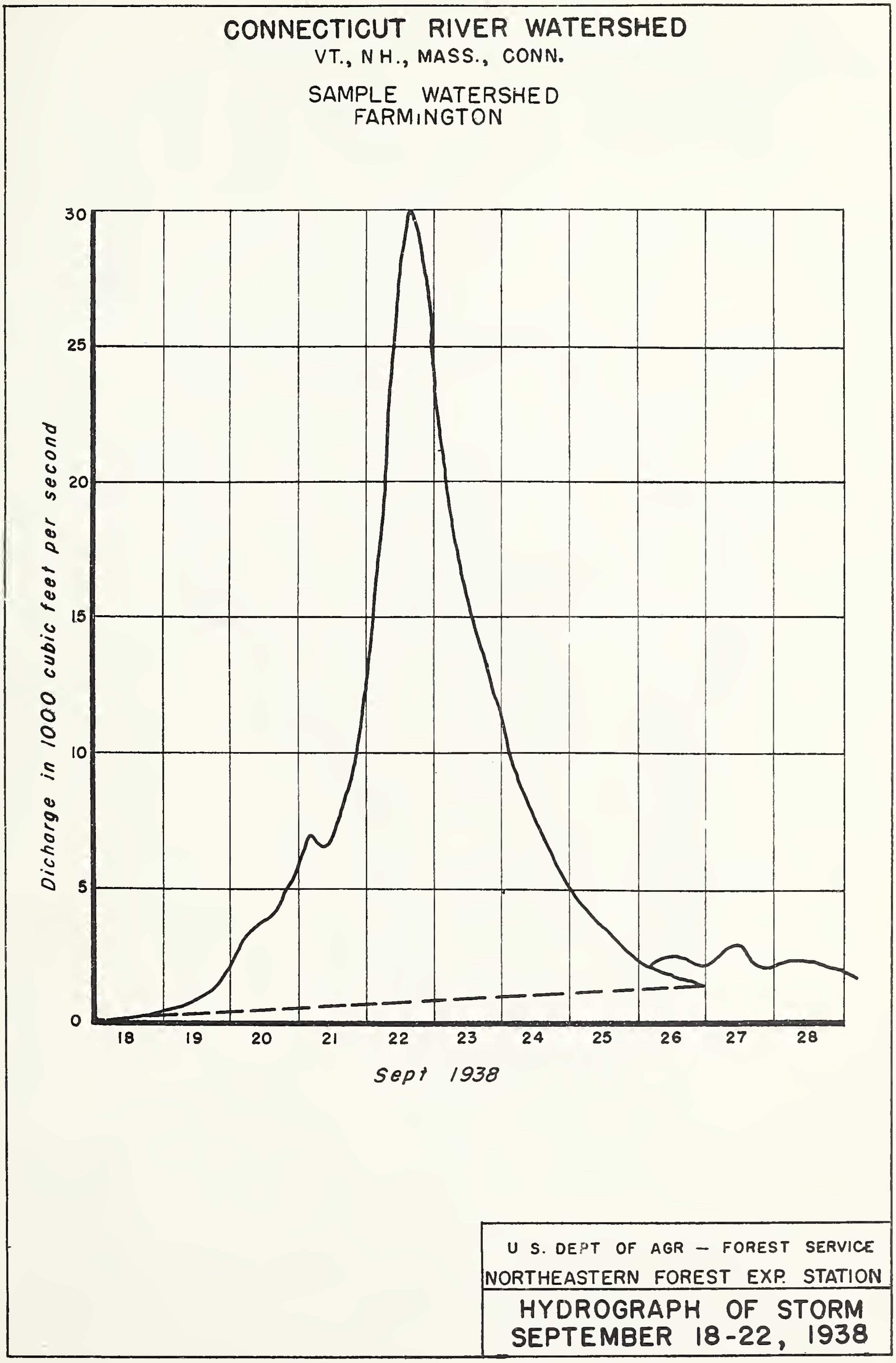
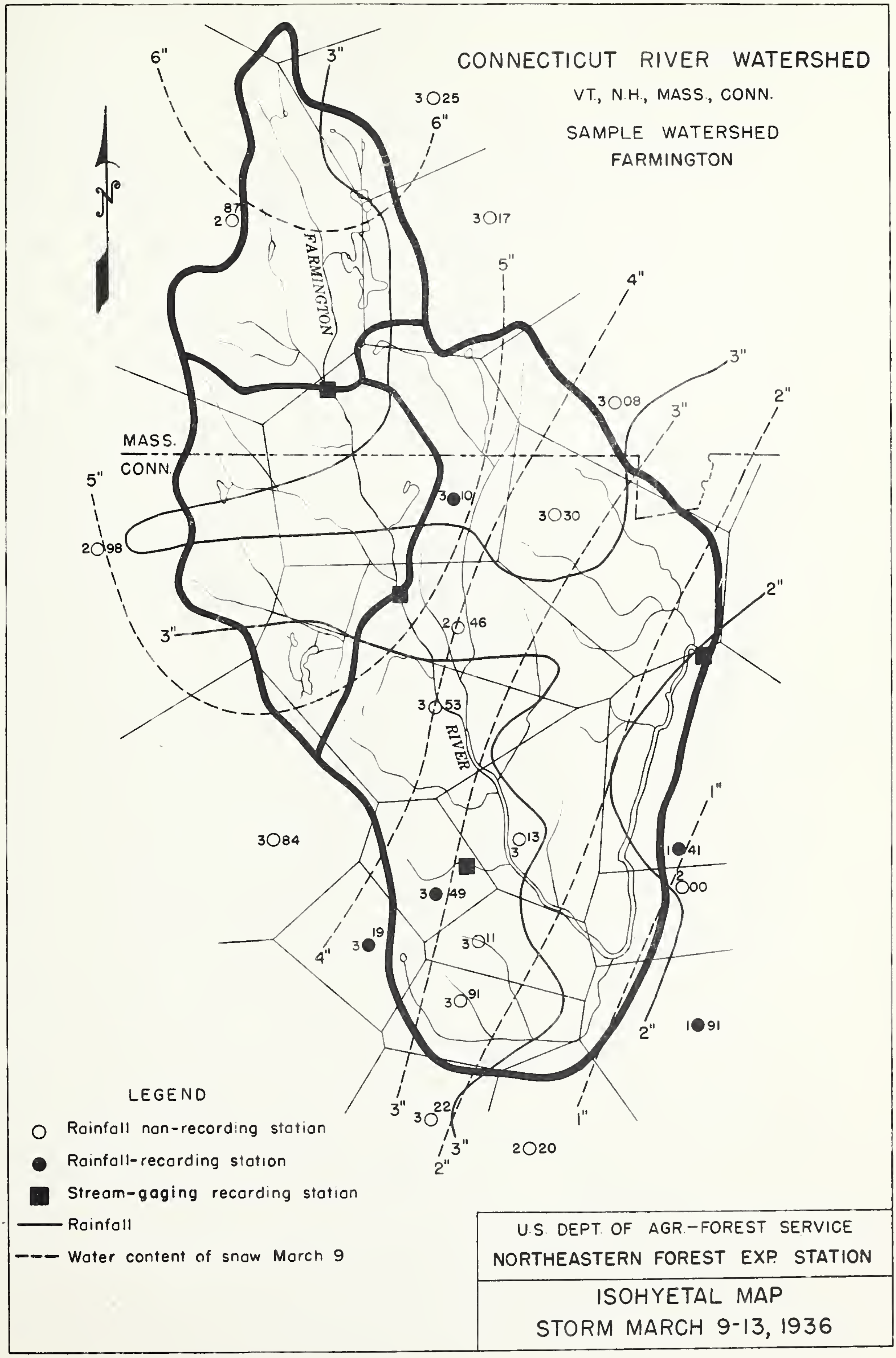
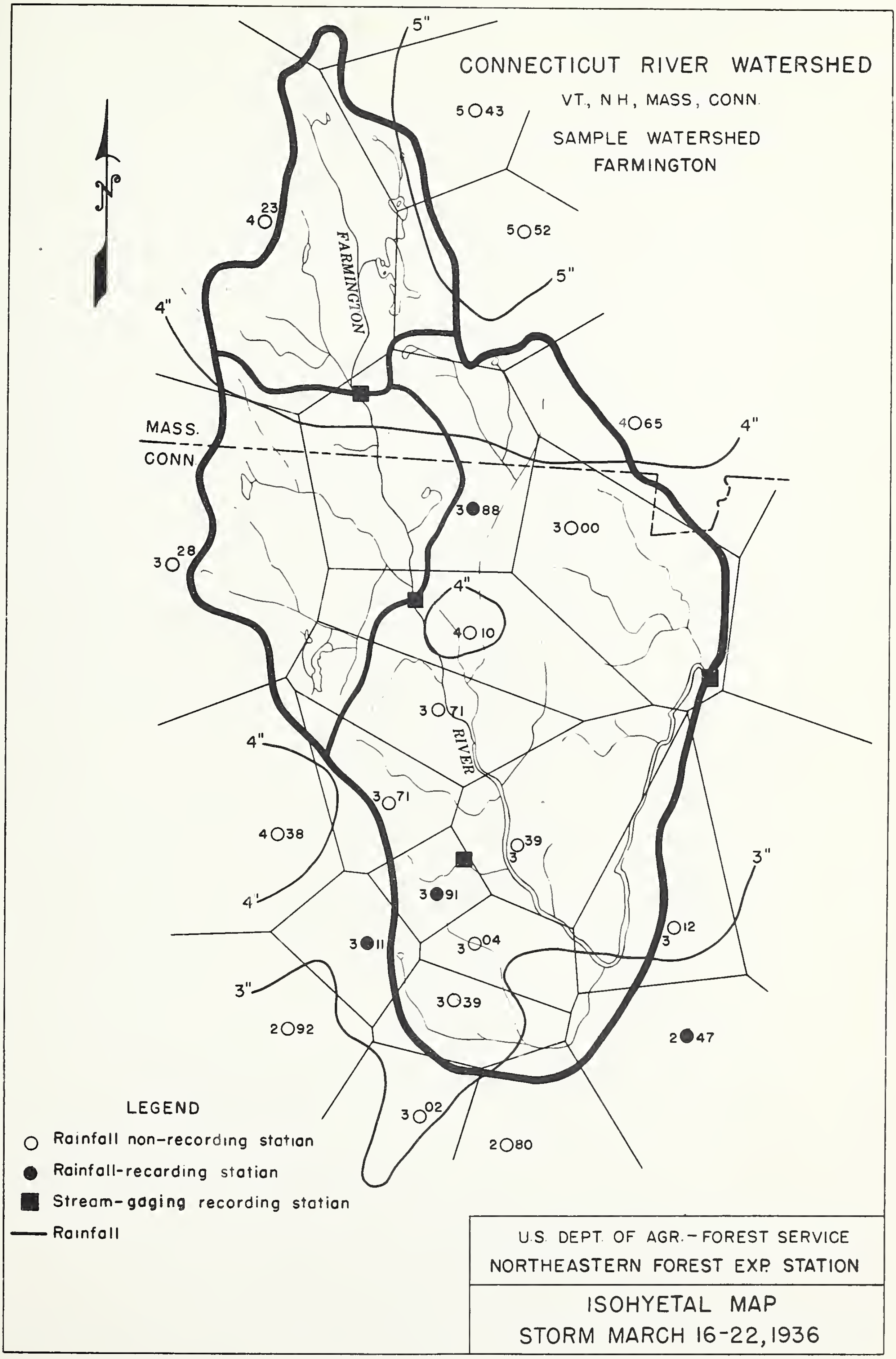

CONNECTICUT RIVER WATERSHED
VT., N H., MASS., CONN.
SAMPLE WATERSHED
FARMINGTON
Dicharge in 1000 cubic feet per second
0
5
10
15
20
25
30
18
19
20
21
22
23
24
25
26
27
28
Sept 1938
U S. DEPT OF AGR — FOREST SERVICE
NORTHEASTERN FOREST EXP. STATION
HYDROGRAPH OF STORM
SEPTEMBER 18-22, 1938

Figure 6



CONNECTICUT RIVER WATERSHED
VT., N.H., MASS., CONN.
SAMPLE WATERSHED
FARMINGTON
FARMINGTON
RIVER
MASS.
CONN.
N
6"
3"
3.25
6"
2.87
3.17
5"
4"
3"
3.08
3"
2"
5"
3.10
3.30
2.98
2"
2.46
3"
3.53
1"
3.84
3.13
1.41
2.00
3.49
3.19
4"
3.11
3.91
2"
1.91
3"
3.22
1"
3"
2"
2.20
LEGEND
Rainfall non-recording station
Rainfall-recording station
Stream-gaging recording station
Rainfall
Water content of snow March 9
U.S. DEPT. OF AGR.–FOREST SERVICE
NORTHEASTERN FOREST EXP. STATION
ISOHYETAL MAP
STORM MARCH 9-13, 1936

Figure 7



CONNECTICUT RIVER WATERSHED
VT., N.H., MASS., CONN.
SAMPLE WATERSHED
FARMINGTON
FARMINGTON
RIVER
MASS.
CONN.
5"
4"
3"
5 43
5 52
4 23
4 65
3 88
3 00
3 28
4 10
3 71
3 71
4 38
3 39
3 91
3 11
3 04
3 12
3 39
2 92
2 47
3 02
2 80
LEGEND
Rainfall non-recording station
Rainfall-recording station
Stream-gaging recording station
Rainfall
U.S. DEPT. OF AGR.-FOREST SERVICE
NORTHEASTERN FOREST EXP. STATION
ISOHYETAL MAP
STORM MARCH 16-22, 1936

Figure 8

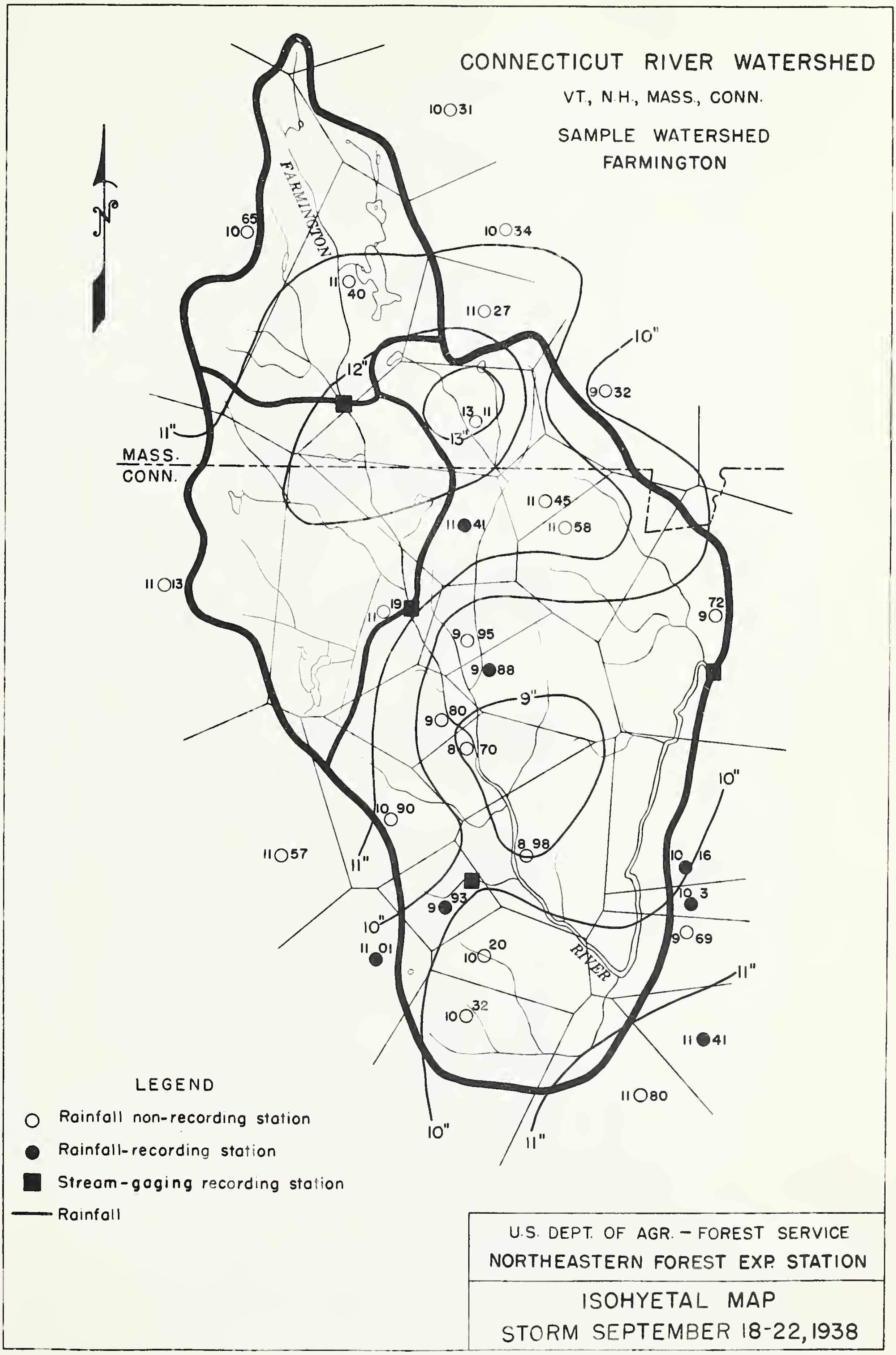

CONNECTICUT RIVER WATERSHED
VT., N.H., MASS., CONN.
SAMPLE WATERSHED
FARMINGTON
N
FARMINGTON
RIVER
MASS.
CONN.
12"
13"
11"
10"
9"
11"
10"
10"
11"
10"
11"
10 31
10 65
10 34
11 40
11 27
9 32
13 11
11 45
11 41
11 58
11 13
11 19
9 72
9 95
9 88
9 80
8 70
10 90
11 57
8 98
10 16
10 3
9 93
9 69
11 01
10 20
10 32
11 41
11 80
LEGEND
Rainfall non-recording station
Rainfall-recording station
Stream-gaging recording station
Rainfall
U.S. DEPT. OF AGR. – FOREST SERVICE
NORTHEASTERN FOREST EXP. STATION
ISOHYETAL MAP
STORM SEPTEMBER 18-22, 1938

Table 13.--Areal extent of soil-cover complexes and infiltration rates of forest in Farmington River watershed, 1947

Soil texture	Forest cover	In good condition		In poor condition			
				Ungrazed		Grazed	
		Area	Infiltration	Area	Infiltration	Area	Infiltration
		Acres	Inches per hour	Acres	Inches per hour	Acres	Inches per hour
Light	Hardwoods	117,530	2.52	38,202	1.03	27,813	0.29
Medium	Hardwoods	23,105	2.36	25,110	1.17	8,549	.57
Light	Mixedwoods	6,260	2.38	3,130	.99	1,899	.29
Medium	Mixedwoods	1,681	2.17	1,293	1.10	517	.57
Light	Pine-hemlock	9,185	1.86	2,923	.81	2,107	.29
Medium	Pine-hemlock	2,586	1.70	1,154	.95	657	.57

total area of the watershed. The total of the weighted rainfall excess for all soil-cover complexes thus represents the total surface runoff for the watershed (table 15).

Table 14.--Areal extent of soil-cover complexes and infiltration rates of open land in Farmington River watershed, 1947

Soil texture	Cover	Area	Infiltration rate
		Acres	Inches per hour
Light	Hay land	18,836	0.75
Medium	Hay land	15,349	.58
Medium	Pasture, lightly grazed	3,041	.57
Medium	Idle land	1,766	.57
Light	Pasture, lightly grazed	3,731	.40
Light	Idle land	2,167	.40
Light	Pasture, heavily grazed	10,640	.29
Medium	Pasture, heavily grazed	8,670	.15
Light	Cropland, clean-tilled	4,854	.25
Medium	Cropland, clean-tilled	3,956	.21
Light & medium	Miscellaneous	4,685	.20

Subsurface runoff.--In shallow soils underlain by an impervious layer, subsurface flow occurs; and this contributes to the stream runoff during the flood period. The amount of the subsurface runoff was determined by "routing" the infiltrated water through the soil-moisture storage. This routing was based on the soil-moisture storage-depletion curves. The soil moisture at the beginning of the flood was determined, since subsurface runoff does not occur until the soil moisture exceeds field capacity. The amount of subsurface runoff will therefore be reduced by the amount of the soil-moisture deficiency. In order to make the subsurface runoff computations, therefore, it was necessary first to compute (1) the amount and rate of water entering the shallow soils by infiltration, (2) the soil-moisture deficiency at beginning of flood, (3) the soil-moisture field capacity, and (4) the soil-moisture storage-depletion curves.

Table 15.--Rainfall excess for all soils as it would have been under a flood control program; computed from 1938 flood of Farmington watershed above Tarriffville, Connecticut

Day	Hour	Rain-fell	Rainfall excess (all soils)														
			Forest, at infiltration rate (inches per hour) of--							Open, at infiltration rate (inches per hour) of--							Urban
			1.17	1.10	1.03	0.99	0.95	0.81	0.57	0.75	0.58	0.57	0.40	0.32	0.26	0.20	0.00
		Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
Sept. 18	2:00- 6:00 p.m.	0.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03
	6:00-10:00	.06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.06
	10:00-10:30	.71	0.13	0.16	0.20	0.21	0.24	0.31	0.43	0.34	0.42	0.43	0.51	0.55	0.58	0.61	.71
	10:30-11:00	.37	-	-	-	-	-	-	.09	-	.08	.09	.17	.21	.24	.27	.37
	11:00-12:00	.24	-	-	-	-	-	-	-	-	-	-	-	-	-	.04	.24
Sept. 19	12:00- 2:00 a.m.	.17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.17
	2:00- 6:00	.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.14
	6:00-10:00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10:00- 2:00 p.m.	.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.01
	2:00- 3:00	.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.04
	3:00- 4:00	.22	-	-	-	-	-	-	-	-	-	-	-	-	-	.02	.22
	4:00- 4:30	.54	-	-	.03	.04	.07	.14	.26	.17	.25	.26	.34	.38	.41	.44	.54
	4:30- 5:00	.11	-	-	-	-	-	-	-	-	-	-	-	-	-	.01	.11
	5:00- 6:00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6:00-10:00	.13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.13
Sept. 20	10:00- 1:00 a.m.	.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.02
	1:00- 1:30	.75	.17	.20	.24	.25	.28	.35	.47	.38	.46	.47	.55	.59	.62	.65	.75
	1:30- 2:00	.10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.10
	2:00- 6:00	.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.03
	6:00- 8:00	.13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.13
	8:00- 9:00	1.00	-	-	-	.01	.05	.19	.43	.25	.42	.43	.60	.68	.74	.80	1.00
	9:00-10:00	.66	-	-	-	-	-	-	.09	-	.08	.09	.26	.34	.38	.46	.66
	10:00- 2:00 p.m.	.07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.07
	2:00- 6:00	.19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.19
	6:00- 8:00	.07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.07
	8:00- 8:30	.75	.17	.20	.24	.25	.28	.35	.47	.38	.46	.47	.55	.59	.62	.65	.75
	8:30- 9:00	.64	.08	.09	.13	.14	.17	.24	.36	.27	.35	.36	.44	.48	.51	.54	.64
	9:00-10:00	.31	-	-	-	-	-	-	-	-	-	-	-	-	.05	.11	.31
	10:00-11:00	.59	-	-	-	-	-	-	.02	-	.01	.02	.19	.27	.33	.39	.59
	11:00-12:00	.48	-	-	-	-	-	-	-	-	-	-	.08	.16	.22	.28	.48
Sept. 21	12:00- 2:00 a.m.	.29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.29
	2:00- 6:00	.39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.39
	6:00-10:00	.39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.39
	10:00- 2:00 p.m.	.07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.07
	2:00- 3:00	.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.14
	3:00- 4:00	.42	-	-	-	-	-	-	-	-	-	-	.02	.10	.16	.22	.42
	4:00- 5:00	.09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.09
Total rainfall excess . . . . .inches			0.55	0.65	0.84	0.90	1.09	1.58	2.62	1.79	2.53	2.62	3.71	4.35	4.86	5.49	10.35
Total area. . . . . .acres			5,365	234	9,598	230	498	445	347	19,314	15,738	13,477	16,538	4,723	3,849	4,685	18,524
Total volume. . . . . acre inches			2,951	152	8,062	207	543	703	909	34,572	39,817	35,310	61,356	20,545	18,706	25,721	191,723
Weighted rainfall excess. . . . . . . .inches			0.008	-	0.022	0.001	0.001	0.002	0.002	0.093	0.108	0.095	0.166	0.055	0.050	0.069	0.518

The amount and rate of water entering the soil by infiltration was determined from the surface runoff computations. The rainfall excess was determined separately for shallow soils. For each time period used, the rainfall excess was weighted and totaled for all soil-cover complexes. The amount of infiltrated water was computed by subtracting the weighted rainfall excess for shallow soils from the rainfall intensity for the same period (table 16).

The soil-moisture deficiency at the beginning of the flood was determined by evaluating the factors that affected the soil moisture since the date it was previously at field capacity. These factors are rainfall, runoff, and evapo-transpiration losses. They were evaluated as follows:

1. The amount of rainfall during the period was obtained by taking a weighted average of the rainfall recorded for the stations in the subwatershed.

2. The amount of runoff for the period is the difference between the actual runoff and what would have occurred if no rain had fallen during this period. A hydrograph (fig. 9) of the actual runoff was plotted for the period from the time the basin was last at field capacity to the beginning of the flood. A recession curve representing the ground-water base flow was drawn on the hydrograph to show what runoff would have been with no rainfall for the period. This difference in runoff was obtained by subtracting the base-flow from the total flow for the period and converting the result to inches of runoff (table 17).

3. On the basis of findings by the Bureau of Reclamation[3/] the evaporation-transpiration losses were computed from the formula:

$$L = KN\ (\text{Tav. Max.} - 32^{\circ}\ \text{F.})$$

in which L = Mass loss in inches during any selected periods of time

K = Loss per degree-day

N = Number of days in period

Tav. Max.= Average daily maximum temperature for the period.

3/ Lowry, R.L.,Jr., and Johnson, Arthur S. The consumptive use of water for agriculture. Amer. Soc. Civ. Engin. Proc. 67(1):595-616.

Table 16.--Rainfall excess for shallow soils as it would have been under a flood control program; computed from 1938 flood of Farmington watershed above Tarriffville, Connecticut

Day	Hour	Rain-fall	Weighted rainfall excess for shallow soils										Net rainfall supply
			Forest, at infiltration rate (inchee per hour) of--						Open, at infiltration rate of--			Total	
			1.17	1.10	1.03	0.99	0.95	0.81	0.75	0.40	0.20		
		Inchee	Inches	Inches	Inches	Inches	Inchee	Inchee	Inchee	Inches	Inchee	Inchee	Inches
Sept. 18	2:00- 6:00 p.m.	0.03	-	-	-	-	-	-	-	-	-	-	0.03
	6:00-10:00	.06	-	-	-	-	-	-	-	-	-	-	.06
	10:00-10:30	.71	0.001	-	0.011	-	-	0.001	-	0.003	0.001	0.017	.69
	10:30-11:00	.37	-	-	-	-	-	-	-	.001	-	.001	.37
	11:00-12:00 m.	.24	-	-	-	-	-	-	-	-	-	-	.24
Sept. 19	12:00- 2:00 a.m.	.17	-	-	-	-	-	-	-	-	-	-	.17
	2:00- 6:00	.14	-	-	-	-	-	-	-	-	-	-	.14
	6:00-10:00	-	-	-	-	-	-	-	-	-	-	-	-
	10:00- 2:00 p.m.	.01	-	-	-	-	-	-	-	-	-	-	.01
	2:00- 3:00	.04	-	-	-	-	-	-	-	-	-	-	.04
	3:00- 4:00	.22	-	-	-	-	-	-	-	-	-	-	.22
	4:00- 4:30	.54	-	-	.002	-	-	-	-	.002	.001	.005	.53
	4:30- 5:00	.11	-	-	-	-	-	-	-	-	-	-	.11
	5:00- 6:00	-	-	-	-	-	-	-	-	-	-	-	-
	6:00-10:00	.13	-	-	-	-	-	-	-	-	-	-	.13
Sept. 20	10:00- 1:00 a.m.	.02	-	-	-	-	-	-	-	-	-	-	.02
	1:00- 1:30	.75	.001	-	.014	-	-	.001	0.001	.004	.001	.022	.73
	1:30- 2:00	.10	-	-	-	-	-	-	-	-	-	-	.10
	2:00- 6:00	.03	-	-	-	-	-	-	-	-	-	-	.03
	6:00- 8:00	.13	-	-	-	-	-	-	-	-	-	-	.13
	8:00- 9:00	1.00	-	-	-	-	-	-	-	.004	.001	.005	.99
	9:00-10:00	.66	-	-	-	-	-	-	-	.002	.001	.003	.66
	10:00- 2:00 p.m.	.07	-	-	-	-	-	-	-	-	-	-	.07
	2:00- 6:00	.19	-	-	-	-	-	-	-	-	-	-	.19
	6:00- 8:00	.07	-	-	-	-	-	-	-	-	-	-	.07
	8:00- 8:30	.75	.001	-	.014	-	-	.001	-	.004	.001	.021	.73
	8:30- 9:00	.64	.001	-	.007	-	-	-	-	.003	.001	.012	.63
	9:00-10:00	.31	-	-	-	-	-	-	-	-	-	-	.31
	10:00-11:00	.59	-	-	-	-	-	-	-	.001	-	.001	.59
	11:00-12:00 m.	.48	-	-	-	-	-	-	-	.001	-	.001	.48
Sept. 21	12:00- 2:00 a.m.	.29	-	-	-	-	-	-	-	-	-	-	.29
	2:00- 6:00	.39	-	-	-	-	-	-	-	-	-	-	.39
	6:00-10:00	.39	-	-	-	-	-	-	-	-	-	-	.39
	10:00- 2:00 p.m.	.07	-	-	-	-	-	-	-	-	-	-	.07
	2:00- 3:00	.14	-	-	-	-	-	-	-	-	-	-	.14
	3:00- 4:00	.42	-	-	-	-	-	-	-	-	-	-	.42
	4:00- 5:00	.09	-	-	-	-	-	-	-	-	-	-	.09
Total rainfall excess. . . . . .inches			0.004	-	0.048	-	-	0.003	0.001	0.025	0.007	0.088	10.26
Total area. . . . . acres			538	67	4,502	64	98	140	77	530	94	--	--
Percent shallow soils			0.69	0.08	5.76	0.08	0.12	0.18	0.10	0.68	0.12	--	--

Figure 9

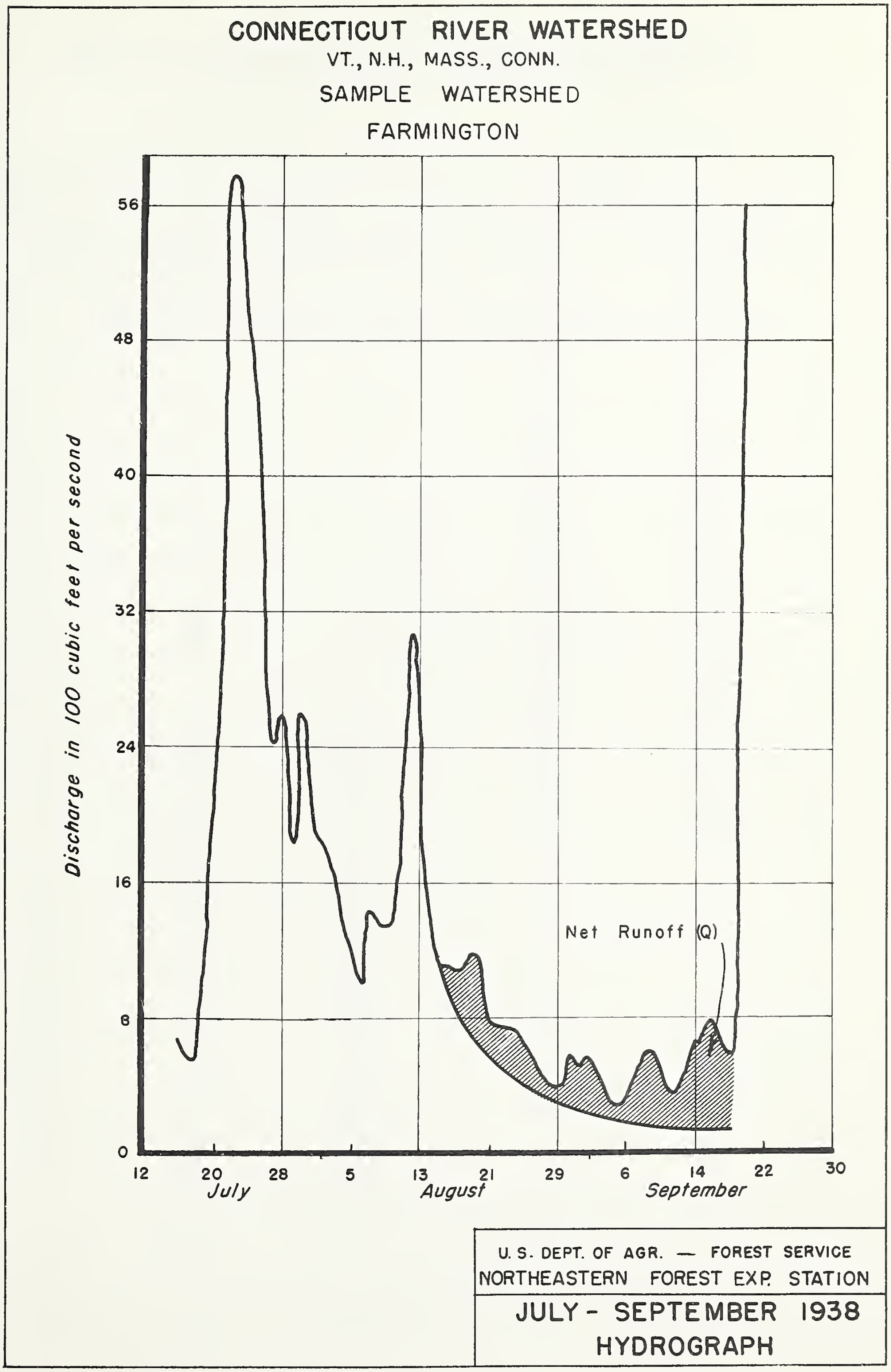

CONNECTICUT RIVER WATERSHED
VT., N.H., MASS., CONN.
SAMPLE WATERSHED
FARMINGTON
Discharge in 100 cubic feet per second
0
8
16
24
32
40
48
56
Net Runoff (Q)
12
20
28
5
13
21
29
6
14
22
30
July
August
September
U. S. DEPT. OF AGR. — FOREST SERVICE
NORTHEASTERN FOREST EXP. STATION
JULY - SEPTEMBER 1938
HYDROGRAPH

Table 17.--Actual runoff and ground-water depletion from August 15 to September 19, 1938

Day of month	August		September	
	Actual runoff	Ground-water depletion	Actual runoff	Ground-water depletion
	Day second-feet	Day second-feet	Day second-feet	Day second-feet
1	--	--	566	240
2	--	--	584	225
3	--	--	462	215
4	--	--	326	205
5	--	--	300	198
6	--	--	346	190
7	--	--	532	180
8	--	--	588	170
9	--	--	602	165
10	--	--	470	160
11	--	--	340	155
12	--	--	370	150
13	--	--	580	145
14	--	--	650	140
15	1,130	1,130	710	137
16	1,130	1,000	790	135
17	1,100	860	650	132
18	1,130	750	580	130
19	1,200	670	--	--
20	1,100	600	--	--
21	768	540	--	--
22	768	490	--	--
23	768	450	--	--
24	728	415	--	--
25	702	380	--	--
26	615	355	--	--
27	512	330	--	--
28	409	305	--	--
29	421	290	--	--
30	563	270	--	--
31	546	255	--	--
Total	13,590	9,090	9,446	3,072

The evaporation-transpiration loss for a watershed is equal to the difference between the rainfall and the runoff for a selected period. The value of K for a watershed was determined by dividing the difference between rainfall and runoff for a period of several years by the total number of degree-days for the same period. The evapo-transpiration loss for the Farmington subwatershed for the period between the time the subwatershed was last at field capacity and the beginning of the flood was determined by multiplying K by the total number of degree-days for the period.

After the above values were determined they were added algebraically to obtain the soil-moisture deficiency.

The computation of soil-moisture deficiency for the Farmington River watershed for September 17, 1938 was made as follows:

1. Runoff:

	Total	Depletion	Net
	Day second-feet	Day second-feet	Day second-feet
August 15-31	13,590	9,090	4,500
September 1-17	9,446	3,072	6,374
Total	--	--	10,874

$$\text{Runoff } (Q) = \frac{10,874}{15,542} = 0.70 \text{ inches}$$

2. Supply, precipitation:

	Hartford	Cream Hill	East Hartland
	Inches	Inches	Inches
August 15-31	0.05	0.45	0.32
September 1-17	1.81	3.00	1.32
Total	1.86	3.45	1.64

Watershed average (P) = 2.32 inches

3. Evaporation-transpiration loss:

Average maximum temperature

Date	Days	Hartford	Cream Hill	Average	Tmax-32	Mass degree days
	Number	°F.	°F.	°F.	°F.	Number
Aug. 15-31	17	82.9	80.3	81.6	49.6	843
Sept. 1-17	17	72.7	70.0	71.3	39.3	668
Total	--	--	--	--	--	1,511

Consumptive use (L) = 0.0019 x 1,511 = 2.87 inches.

4. Field capacity:

Watershed average (F_c) = 3.05 inches

5. Soil-moisture storage:

$$\begin{aligned}\text{Soil moisture } (S_m) &= F_c + P - Q - L\\ &= 3.05 + 2.32 - 0.70 - 2.87\\ &= 1.80\end{aligned}$$

6. Soil-moisture deficiency:

Soil-moisture deficiency = $F_c - S_m$ = 3.05 - 1.80 = 1.25 inches.

Soil-moisture storage-depletion curves were based on field samples of the soil profile for the six major humus types and the mineral soil. Samples were taken on both a weight and volume basis and were converted to moisture percent per unit volume. Plots were selected in areas of a distinct humus type. The plots were of about one-quarter acre in size, on a uniform slope. Soil wells were excavated into the C horizon. The sides of the holes were cut clean to facilitate identification of the horizons.

The weight samples for shallow humus were taken by first removing the litter from the sides of the soil well. A soil-sample can ($2\frac{1}{2}$ inches in diameter and 2 inches deep) was pressed into the humus. Any mineral soil clinging to the extracted humus samples was removed. For deep humus and mineral soils the soil can was pressed into the horizon from the side of the hole. These samples were taken about the

same time each day. Volume-weight samples were obtained by the standard-cylinder (Burger) method with slight modifications to fit conditions in each horizon. The sample was placed in a soil can immediately after sampling. In the laboratory the samples were dried at temperatures less than 90° Centigrade; the percentage of water by weight and volume-weight of each sample was computed by an oven-dry weight basis. All moisture determinations based on weight were converted to cubic inches of water per cubic inch of soil.

From these data soil-moisture depletion curves (fig. 10) were drawn for each of the humus types and the mineral soil. These curves show how each soil horizon is depleted in time from maximum storage to below field capacity. The total moisture in the soil profile was then computed at any time of depletion by multiplying the depth of each horizon by the moisture content per inch and adding these values. It was found from a study of soil-survey maps of the watershed that the average depth of the mineral horizon in shallow soils is 18 inches.

The storage-depletion curve for the basin was computed by weighting the total moisture in the soil by the areal extent of each soil-cover complex. Storage-depletion curves were also computed both for present conditions and for the estimated future conditions under a flood-control program. This was done to show how deeper humus and increased porosity of the soil--to be achieved by the program--will increase the soil's moisture-holding capacity. Curves were also computed for summer and winter conditions, since in the winter, with frost conditions, infiltration occurs only on good forest soils.

The average field capacity was determined from estimates made of the above-mentioned samples and from moisture equivalents for various soils from U. S. Geological Survey data4/.
The field capacity of each soil-cover complex was weighted areally to obtain the average field capacity for the basin.

A curve of the rate of depletion of soil moisture per hour against storage was determined by dividing successive increments of storage by the corresponding time period in hours (fig. 10).

4/ U.S.Geological Survey. U.S.Geol. Survey Water-Supply Paper 494. 71 pp. 1923

The method of "routing" water infiltrated into the soil during flood periods was as follows:

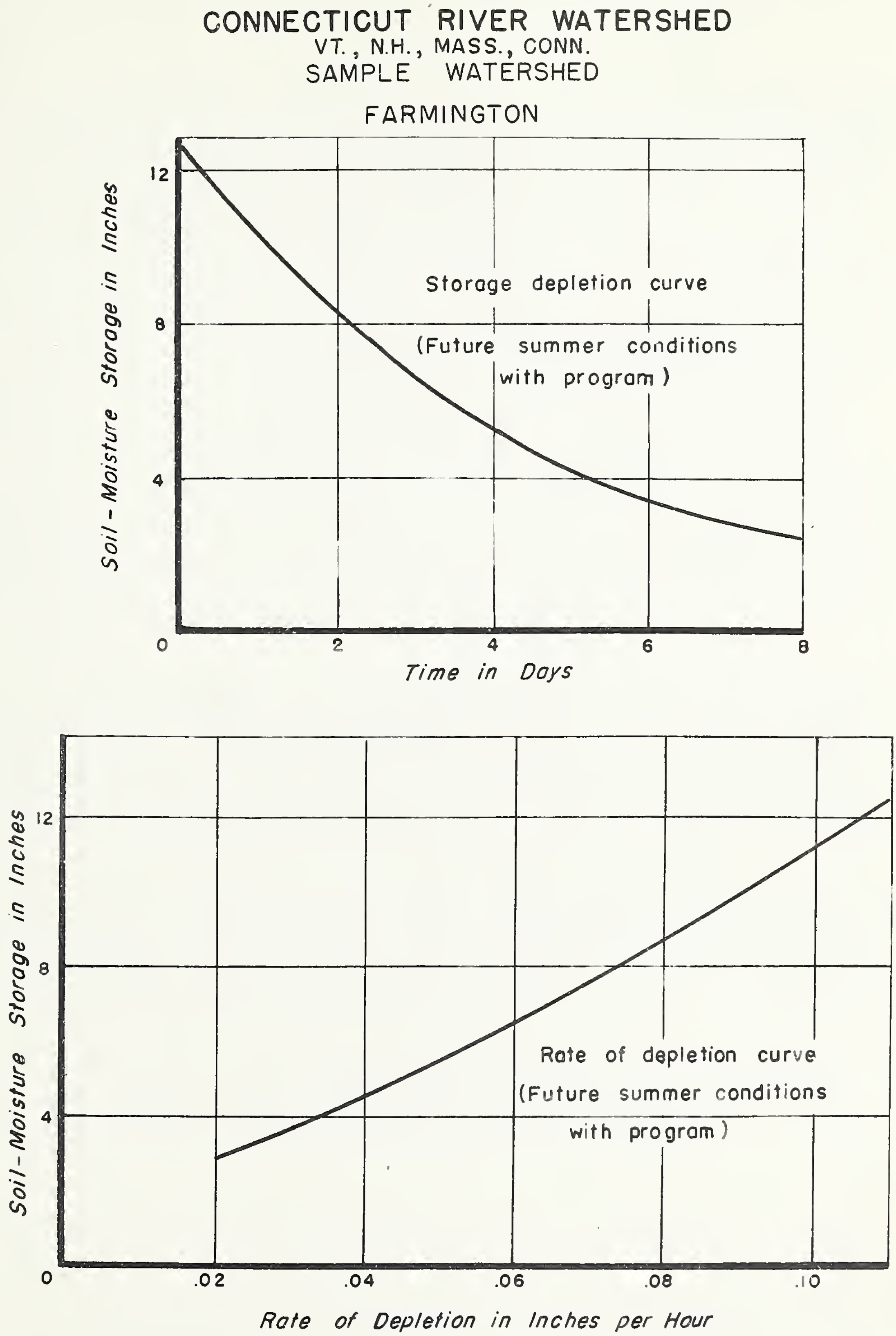
> The soil moisture at the beginning of the flood was computed by subtracting soil-moisture deficiency from field capacity. Then the computed amounts of infiltrated water were added to the soil-moisture storage at the beginning of the flood; this was done by 4-hour increments until the storage equaled field capacity. At this point there was no soil-moisture deficiency, and additional 4-hour increments of infiltrated water built up the storage above field capacity.
>
> Next, the depletion was determined by trial-and-error methods. The rate of depletion was estimated from a soil-moisture storage-depletion curve that corresponded to an assumed average soil-moisture storage for the 4-hour period. The rate of depletion (per hour) was multiplied by 4 hours, and the result was subtracted from the soil-moisture storage at the beginning of the 4-hour period. The average soil-moisture storage was computed for the beginning and the end of the 4-hour period. As a check, the rate of depletion was determined from the storage-depletion curve by means of the average soil-moisture storage figure. If there was a difference between the estimated depletion and the computed depletion, this process was repeated until these two values checked.

This procedure was continued until the soil-moisture storage returned to field capacity. If, during the computations, the average soil-moisture storage exceeded maximum soil-moisture storage capacity, the excess was considered spill that occurred as surface runoff. The total amount of depletion and spill was obtained by adding the figures for the 4-hour period.

<u>Computed runoff for present conditions</u>.--The total computed runoff equaled the sum of the rainfall excess computed for shallow and deep soils, plus the depletion and spill runoff prorated according to the areal extent of the shallow soils. The computed runoff was checked against the actual runoff obtained from the hydrograph and the runoff withheld by reservoir storage from the flood hydrograph.

<u>Estimated runoff for future conditions</u>.--The estimated future runoff with a land-use program was computed from the proposed areal distribution of the soil-cover complexes. On shallow soils the reduction in flood volume was obtained

Figure 10



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SOIL-MOISTURE DEPLETION CURVES

through decreased rainfall-excess due to better infiltration conditions, greater potential soil-moisture deficiency due to the increase in field capacity, and the delay in runoff due to the change from surface to subsurface flow. The field capacity and storage-depletion curves were computed for the humus build up and consequent structural improvement of the soil under future conditions. The soil-moisture deficiency for the future was computed by increasing the deficiency for present conditions by the percentage increase in field capacity. The reduction in runoff attributable to increased infiltration of shallow soils was computed by prorating the difference between the rainfall excess on shallow soil for present and future conditions, according to the ratio of the volume of depletion from the time of peak discharge to the end of the flood to the total volume of depletion. As this amount does not contribute to flood crests, this reduction was then subtracted from the total volume of runoff under future conditions.

On deep soils the flood reduction is due to the greater area with higher infiltration rates. Since all reductions are equally effective throughout the storm, the reduction in discharge is proportional to the decrease in flood volumes between present and future conditions. The same storms were used in analyzing both present and future volume of runoff.

It was assumed for future conditions that the same reservoir storage would be available during a recurrence of the September 1938 storm. The percent reduction in volume can therefore be applied directly to the actual volume of runoff obtained from the hydrograph.

The results of the computation of flood volume for the September 18-22, 1938, flood on the Farmington River watershed under future conditions are as follows:

	Present (Inches)	Future (Inches)
Precipitation	10.35	10.35
Runoff from impervious areas	.52	.52
Runoff from rainfall excess	1.37	.67
Runoff from depletion of temporary storage	1.86	1/ 1.87
Total calculated runoff	3.75	3.06
Actual runoff from hydrograph	3.83	--
Runoff withheld from hydrograph by reservoir storage	.71	--
Total actual runoff	4.54	--
Volume reduction	--	.69
Volume reduction at peak by shallow soil	--	2/ .03
Total volume reduction, in inches	--	.72
Volume reduction, in percent	--	19.20

1/ Total runoff from temporary storage =

$$(8.78)\ \frac{78,822}{369,920} = 1.87 \text{ inches.}$$

2/ Volume reduction at peak by shallow soils =

$0.28 \times \frac{4.59}{8.78} \times \frac{78,822}{369,920} = 0.03$ inches. In this formula 0.28 inches is the difference between rainfall excess on shallow soils for present and future conditions.

Winter floods.--In estimating winter floods the amount of water available from snow melt was added to rainfall chronologically by 4-hour periods. When impervious frost conditions exist, infiltration is inhibited on all soil-cover complexes except "good" forest. Therefore, all soil-cover complexes except "good" forest were assumed to result in 100-percent runoff. In the case of "good" forest on deep soils, the infiltration rate was higher than that of the rate of precipitation and the infiltrated water did not contribute to flood runoff. In the case of "good" forest on shallow soils, the depletion of storage (table 19) was computed the same way as for a summer flood.

Table 18.--Runoff from temporary storage as it would have been under a flood-control program; computed from 1938 flood of Farmington River above Tarriffville, Connecticut

Date	Hour	Net rainfall supply	Storage			Runoff from storage
			Start period	End period	Average	
		Inches	Inches	Inches	Inches	Inches
--	--	--	--	1/ 2.12	--	--
Sept. 18	2- 6 p.m.	0.03	2.15	2.15	--	--
	6-10	.06	2.21	2.21	--	--
Sept. 19	10- 2 a.m.	1.47	3.68	3.65	3.62	0.03
	2- 6	.14	3.79	3.67	3.66	.12
	6-10	--	3.67	3.60	3.63	.07
	10- 2 p.m.	.01	3.61	3.60	3.60	.01
	2- 6	.90	4.50	4.37	3.98	.13
	6-10	.13	4.50	4.35	4.36	.15
Sept. 20	10- 2 a.m.	.85	5.20	5.03	4.69	.17
	2- 6	.03	5.06	4.88	4.96	.18
	6-10	1.78	6.66	6.45	5.66	.21
	10- 2 p.m.	.07	6.52	6.28	6.36	.24
	2- 6	.19	6.47	6.23	6.36	.24
	6-10	1.74	7.97	7.71	6.97	.26
Sept. 21	10- 2 a.m.	1.36	9.07	8.76	8.24	.31
	2- 6	.39	9.15	8.83	8.80	.32
	6-10	.39	9.22	8.89	8.86	.33
	10- 2 p.m.	.07	8.96	8.64	8.76	.32
	2- 6	.65	9.29	8.97	8.80	.32
	6-10	--	8.97	8.65	8.81	.32
Sept. 22	10- 2 a.m.	--	8.65	8.34	8.50	.31
	2- 6	--	8.34	8.04	8.19	.30
	6-10	--	8-04	7.75	7.90	.29
	10- 2 p.m.	--	7.75	7.47	7.61	.28
	2- 6	--	7.47	7.20	7.34	.27
	6-10	--	7.20	6.94	7.07	.26
Sept. 23	10- 2 a.m.	--	6.94	6.69	6.82	.25
	2- 6	--	6.69	6.44	6.56	.25
	6-10	--	6.44	6.20	6.32	.24
	10- 2 p.m.	--	6.20	5.97	6.08	.23
	2- 6	--	5.97	5.75	5.86	.22
	6-10	--	5.75	5.54	5.64	.21
Sept. 24	10- 2 a.m.	--	5.54	5.34	5.44	.20
	2- 6	--	5.34	5.15	5.24	.19
	6-10	--	5.15	4.97	5.06	.18
	10- 2 p.m.	--	4.97	4.79	4.88	.18
	2- 6	--	4.79	4.62	4.70	.17
	6-10	--	4.62	4.46	4.54	.16
Sept. 25	10- 2 a.m.	--	4.46	4.31	4.38	.15
	2- 6	--	4.31	4.16	4.24	.15
	6-10	--	4.16	4.02	4.09	.14
	10- 2 p.m.	--	4.02	3.89	3.96	.13
	2- 6	--	3.89	3.76	3.82	.13
	6-10	--	3.76	3.64	3.70	.12
	10-11	--	3.64	3.61	3.62	.03
	11-12	--	3.61	3.60	--	.01
Total		10.26				8.78

1/ Soil-moisture content at beginning of storm, equals field capacity minus soil-moisture deficiency, based on the following data:

	Inches
Soil-moisture deficiency	1.48
Field capacity	3.60
Maximum storage	12.24

The computation of flood volume for the March 16-22, 1936, flood under present watershed conditions and under future conditions with a flood-control program follows:

1. Present and future land use, by area:

	Present (Acres)	Future (Acres)
Open land	77,695	78,324
Urban, roads, and waterways	18,524	18,524
Forest, deep soils, good infiltration	114,474	183,545
Forest, shallow soils, good infiltration	45,873	72,810
Forest, deep and shallow soils, poor infiltration; and forest, grazed	113,354	16,717
Total	369,920	369,920
Forest, shallow soil, poor infiltration; and forest, grazed	31,395	5,409

2. Result of flood volume computations:

	Present (Inches)	Future (Inches)
Precipitation	6.05	6.05
Runoff from areas with zero infiltration	3.27	1.59
Runoff from temporary storage	.80	1.27
Runoff from spill above maximum storage	.00	.00
Total calculated runoff	4.07	2.86
Actual runoff from hydrograph	4.01	--
Flood reduction	--	1.21
Volume reduction at peak by shallow soils	--	.20
Total volume reduction, in inches	--	1.41
Total volume reduction, in percent		34.6

Table 19.--Runoff from temporary storage in shallow soils; actual conditions of 1936 flood on Farmington watershed above Tariffville, Connecticut, and conditions of same flood under a flood-control program

Situation						Actual conditions				Conditions under flood-control program			
Day	Hour	Rain	Snow melt		Snow melt and rain in forest	Storage			Runoff	Storage			Runoff
			Open	Forest		Start period	End period	Average		Start period	End period	Average	
		Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
--	--	--	--	--	--	--	1/ 3.05	--	--	--	--	--	--
March 15	4:00 p.m.	--	0.10	0.07	0.07	3.12	3.05	3.08	0.07	3.74	3.67	3.67	0.07
	8:00	--	.10	.07	.07	3.12	3.05	3.08	.07	3.74	3.67	3.67	.07
	12:00	--	.04	.03	.03	3.08	3.05	3.05	.03	3.70	3.67	3.67	.03
March 16	4:00 a.m.	--	.02	--	--	3.05	3.05	3.05	--	3.67	3.67	3.67	--
	8:00	--	.01	.01	.01	3.06	3.05	3.05	.01	3.68	3.67	3.67	.01
	12:00	--	.08	.05	.05	3.10	3.05	3.05	.05	3.72	3.67	3.67	.05
	4:00 p.m.	--	.08	.04	.04	3.09	3.05	3.05	.04	3.71	3.67	3.67	.04
	8:00	--	.13	.09	.09	3.14	3.05	3.05	.09	3.76	3.67	3.67	.09
	12:00	--	.38	.24	.24	3.29	3.18	3.12	.11	3.91	3.79	3.74	.12
March 17	4:00 a.m.	--	.24	.22	.22	3.40	3.28	3.23	.12	4.01	3.89	3.84	.12
	8:00	--	--	.27	.27	3.55	3.43	3.35	.12	4.16	4.03	3.96	.13
	12:00	--	--	.47	.47	3.90	3.75	3.59	.15	4.50	4.36	4.19	.14
	4:00 p.m.	--	--	.63	.63	4.38	4.21	3.98	.17	4.99	4.83	4.60	.16
	8:00	--	--	.44	.44	4.65	4.46	4.33	.19	5.27	5.08	4.96	.19
	12:00	--	--	--	--	4.46	4.27	4.36	.19	5.08	4.89	4.98	.19
March 18	4:00 a.m.	0.13	--	--	.13	4.40	4.21	4.24	.19	5.02	4.84	4.86	.18
	8:00	.47	--	--	.47	4.68	4.49	4.35	.19	5.31	5.12	4.98	.19
	12:00	.82	--	--	.82	5.31	5.10	4.75	.21	5.94	5.73	5.42	.21
	4:00 p.m.	.92	--	--	.96	6.06	5.82	5.46	.24	6.69	6.45	6.09	.24
	8:00	.53	--	--	.53	6.35	6.10	5.96	.25	6.98	6.72	6.58	.26
	12:00	.06	--	--	.06	6.16	5.91	6.00	.25	6.78	6.52	6.62	.26
March 19	4:00 a.m.	--	--	--	--	5.91	5.66	5.78	.25	6.52	6.27	6.39	.25
	8:00	--	--	--	--	5.66	5.42	5.54	.24	6.27	6.03	6.15	.24
	12:00	--	--	--	--	5.42	5.19	5.30	.23	6.03	5.80	5.92	.23
	4:00 p.m.	--	--	--	--	5.19	4.96	5.08	.23	5.80	5.57	5.69	.23
	8:00	--	--	--	--	4.96	4.74	4.85	.22	5.57	5.36	5.46	.21
	12:00	--	--	--	--	4.74	4.53	4.64	.21	5.36	5.16	5.26	.20
March 20	4:00 a.m.	--	--	--	--	4.53	4.33	4.43	.20	5.16	4.97	5.06	.19
	8:00	--	--	--	--	4.33	4.14	4.23	.19	4.97	4.79	4.88	.18
	12:00	--	--	--	--	4.14	3.96	4.05	.18	4.79	4.62	4.71	.17
	4:00 p.m.	--	--	--	--	3.96	3.79	3.88	.17	4.62	4.46	4.54	.16
	8:00	--	--	--	--	3.79	3.64	3.71	.15	4.46	4.31	4.39	.15
	12:00	--	--	--	--	3.64	3.50	3.57	.14	4.31	4.17	4.24	.14
March 21	4:00 a.m.	.29	--	--	.29	3.79	3.65	3.57	.14	4.46	4.32	4.24	.14
	8:00	.58	--	--	.58	4.23	4.07	3.86	.16	4.90	4.74	4.53	.16
	12:00	--	--	--	--	4.07	3.90	3.99	.17	4.74	4.58	4.67	.16
	4:00 p.m.	--	--	--	--	3.90	3.74	3.83	.16	4.58	4.42	4.50	.16
	8:00	--	--	--	--	3.74	3.59	3.67	.15	4.42	4.27	4.34	.15
	12:00	--	--	--	--	3.59	3.45	3.52	.14	4.27	4.13	4.20	.14
March 22	4:00 a.m.	--	--	--	--	3.45	3.32	3.38	.13	4.13	4.00	4.07	.13
	8:00	--	--	--	--	3.32	3.20	3.26	.12	4.00	3.87	3.94	.13
	12:00	--	--	--	--	3.20	3.09	3.14	.11	3.87	3.75	3.81	.12
	4:00 p.m.	--	--	--	--	3.09	3.05	3.07	.04	3.75	3.67	3.68	.08
	8:00	--	--	--	--	--	--	--	--	--	--	--	--
	12:00	--	--	--	--	--	--	--	--	--	--	--	--
Total		3.80	1.18	2.63	6.43				6.43				6.43

1/ Soil moisture content at beginning of storm, equals field capacity minus soil-moisture deficiency, based on the following data:

	Actual (Inches)	Future (Inches)
Soil-moisture deficiency	0	0
Field capacity	3.05	3.67
Maximum storage	10.72	12.30

3. Runoff for areas with 0.00 infiltration:

Present | **Future**

Open Areas

$$(3.80 + 1.18)\ \frac{77,695 + 18,524}{369,920} = 1.30 \qquad (3.80 + 1.18)\ \frac{78,324 + 18,524}{369,920} = 1.30$$

Forest, Poor Infiltration;
and Forest, Grazed

$$(3.80 + 2.63)\ \frac{113,354}{369,920} = 1.97 \qquad (3.80 + 2.63)\ \frac{16,717}{369,920} = 0.29$$

4. Runoff from temporary storage:

Present | **Future**

$$6.43\ \frac{45,873}{369,920} = 0.80 \qquad 6.43\ \frac{72,810}{369,920} = 1.27$$

5. Average snow melt over watershed:

$$\frac{1.18\ (77,695 + 18,524 + 2.63\ (114,474 + 45,873 + 113,354)}{369,920} = 2.25$$

6. Volume reduction of peak by shallow soils:

$$\frac{26,937}{369,920} \times 2.83 = 0.20$$

FLOOD REDUCTIONS

Flood reductions were computed in detail on several watersheds. These results were analyzed to determine what land-use changes produced a significant reduction in flood runoff. In summer floods the elimination of grazed woodlots and heavily grazed pasture contributed the greatest reduction. Other reductions were due mostly to the improvement of "poor" forest to "good", and the increase of infiltration rates on clean-tilled cropland and pastures by improved land practices. Other changes in land use would result principally

in maintaining the farm economy or reducing sedimentation damage. In winter floods the principal flood reduction was due to the elimination of grazed woodlots and the improvement of "poor" forest to "good".

Summer flood reductions for areas where detailed computations were not made were based on the average September 1938 rainfall-intensity pattern. The areal extent of the significant soil-cover complexes was determined for all large watersheds. The reduction of runoff was computed by applying the reductions obtainable from land-use conversion and management practices. Winter flood reductions were based on the relative change from "poor" and grazed forest to "good" forest. The summer and winter flood reductions were averaged (table 20) since the damage caused by the greater frequency of winter floods is offset by the greater severity of summer floods.

FLOOD FREQUENCY

Flood frequencies were computed only for watersheds where detailed runoff computations were made. In computing frequency the following equation was used:

$$C = \frac{n}{m - 0.5}$$

--in which "C" is the probable frequency, in years, of recurrence of a given value of discharge; "m" is the number of times during the period of record that the given discharge has been equalled or exceeded; and "n" is the number of years of record.

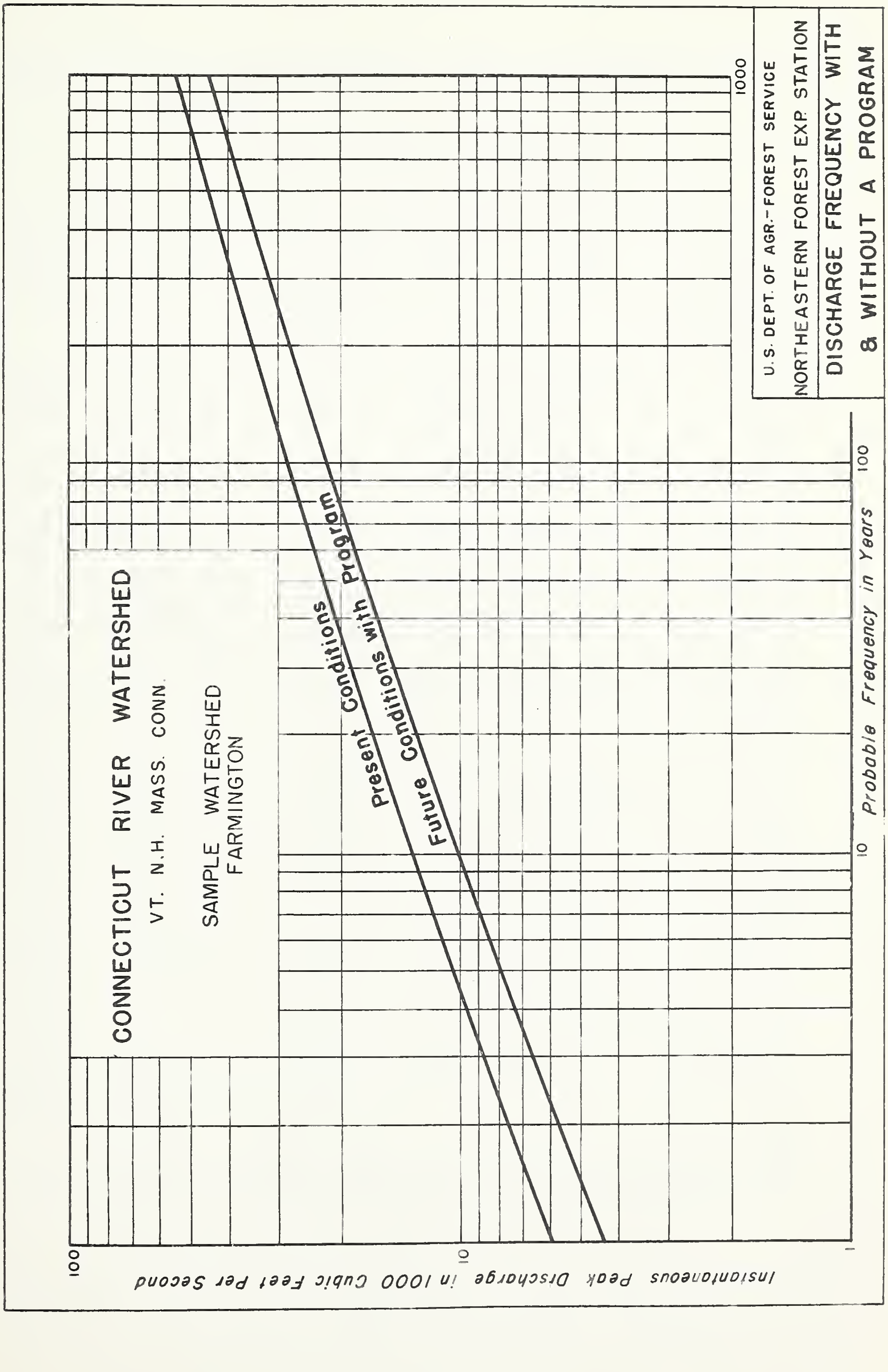
Instantaneous peak discharges were plotted against their frequency of occurrence. A smooth curve drawn through the plotted points give a discharge-frequency curve for present conditions. A similar curve for future conditions was obtained by plotting reduced flood-peak discharge at the same frequency as the original flood (fig. 11).

Actual flood occurrence over the past 110 years is shown in table 21. During this period 29 major floods were recorded at Hartford, Conn., an average of one every 3.8 years. Records have been maintained at Hartford for over 300 years (1639-1950). In the first 200 years of record, 1639-1840, only 18 major floods were recorded, an average of one every 11.6 years.

Table 20.--Average flood reductions under a flood-control program on the Connecticut River watershed

Area	Drainage area	Average flood reduction
	Square miles	Percent
Entire watershed	11,260	16.3
Subwatershed:		
Connecticut above Fifteen Mile Falls	1,650	18.7
Ammonoosuc	393	14.5
Mascoma	153	15.3
Sugar	269	15.6
Ashuelot	420	19.0
Passumpsic	423	11.4
Stevens	49	10.5
Wells	99	14.7
Waits	156	9.7
White	690	10.2
Ottauquechee	221	11.1
Black	158	12.8
Saxtons	78	14.1
West	308	16.8
Deerfield	362	16.6
Millers	370	16.4
Chicopee	703	13.5
Westfield	497	17.5
Scantic	98	21.6
Hockanum	74	21.8
Farmington	578	22.5
Salmon	105	22.5

Figure 11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DISCHARGE FREQUENCY WITH
& WITHOUT A PROGRAM
CONNECTICUT RIVER WATERSHED
VT. N.H. MASS. CONN.
SAMPLE WATERSHED
FARMINGTON
Present Conditions
Future Conditions with Program
Probable Frequency in Years
Instantaneous Peak Discharge in 1000 Cubic Feet Per Second
1
10
100
1000

Table 21.--Crest stages of major floods at Hartford, Conn., 1841-1950

(Flood stage: 16 feet)

Year	Date	Stage	Year	Date	Stage
		Feet			Feet
1841	January 9	26.3	1900	February 15	23.4
1843	March 29	27.2	1901	April 9	26.4
1852	April 24	23.1	1902	March 4	25.5
1854	May 1	29.8	1903	March 25	23.3
1856	August 22	23.3	1905	April 2	24.0
1859	March 20	26.4	1909	April 17	24.7
1862	April 21	28.7	1913	March 29	26.3
1865	March 20	24.8	1922	April 14	24.5
1869	April 23	26.7	1927	November 6	29.0
1869	October 6	26.3	1933	April 21	26.0
1870	April 21	23.3	1934	April 14	23.1
1874	January 9	23.9	1936	March 21	37.6
1893	May 6	24.0	1938	September 23	35.0
1895	April 16	25.7	1940	May 7	23.4
1896	March 3	26.5			

BENEFITS OF THE RECOMMENDED PROGRAM

Two types of tangible benefits will accrue from the installation and maintenance of the recommended program. They are: (1) floodwater and sediment reduction benefits and (2) conservation benefits. Average annual benefits are estimated to be about $20,160,195 when all measures are fully effective.

Intangible benefits, such as savings in lives, relief from mental distress, and fewer interruptions in community service were not evaluated.

REDUCTION IN FLOOD AND SEDIMENT DAMAGES

Benefits were determined separately for reduction in damages (1) from floodwaters, (2) from gullying, sedimentation, and stream-bank erosion, (3) to land values. Estimated average annual benefits from installation of the total needs program are about $1,454,300 (table 22). Of this amount it is estimated that $287,845 (19.8 percent) will accrue to the current programs and $1,166,455 to the recommended program.

Two methods were used to determine average annual benefits resulting from floodwater reduction. On tributaries in the lower portion of the Connecticut watershed, including the Scantic and Farmington Rivers to the mouth of the Connecticut River, flood-frequency curves were developed to show anticipated flood frequencies 50 years after the program is installed. From these frequency curves, damage-frequency curves were prepared. The difference between the average annual damages as computed from the damage-frequency curves based on present conditions and the damage-frequency curves based on future conditions represents the average annual benefits at 50 years. Neither present nor future frequencies on these streams is affected by U. S. Corps of Engineers' structures.

On the remainder of the watershed, including the main stem of the Connecticut River, a different approach was used. From the Corps of Engineers' data, curves were drawn for each tributary for which data were available. showing the relation between the percent reduction in damages and the percentage reduction in peak flows. From these curves a weighted curve was prepared for use on those tributaries for which no data were available. A separate curve was drawn for use on the main Connecticut River.

Table 22.--Estimated average annual flood reduction benefits when flood-control program is fully effective

Kind of benefit	Value in reduction of average annual damages[1] by installation of--		
	Total program	Current program	Recommended program
Reduction of floodwaters:			
Connecticut River[2]	$ 18,500		
Connecticut River[3]	357,700		
Upper Ammonoosuc	1,700		
Israel	600		
Passumpsic	36,700		
Stevens	3,000		
Ammonoosuc	40,800		
Wells	21,000		
Waits	300		
Ompompanoosuc	8,100		
White	33,000		
Mascoma	16,000		
Ottauquechee	17,000		
Sugar	14,700		
Black	48,800		
Williams	12,200		
Saxtons	1,400		
West	4,500		
Ashuelot	61,100		
Millers	30,900		
Deerfield	103,000		
Chicopee	89,500		
Westfield	93,000		
Scantic	12,100		
Farmington	59,400		
Park	10,400		
Hockanum	43,800		
Mattabesset	7,700		
Salmon	8,900		
Eight Mile	9,600		
Miscellaneous watersheds	95,000		
Total, floodwater reduction	$1,260,400	$272,246	$988,154
Reduction of:			
Gullying	1,000	333	667
Sedimentation	44,900	14,966	29,934
Stream-bank erosion	5,800	300	5,500
Enhancement of land values (annual basis)	142,200	--	142,200
Total, all benefits	$1,454,300	$287,845	$1,166,455

1/ Average annual damages not subject to control by Corps of Engineers' program (8 reservoirs and 9 dikes). 2/ Above Fifteen Mile Falls. 3/ From Fifteen Mile Falls to mouth (Corps of Engineers' zones C-1 to C-10).

The percentage reduction in peak flows after the program becomes fully effective was determined, and the corresponding reduction in damages was read directly from the curves.

Average annual benefits accruing from the Corps of Engineers' program of five reservoirs and nine levees were not included in the estimate of benefits from the land-management program.

Destruction of land by sheet and gully erosion that results in sedimentation of bottom lands will be reduced 75 percent within 13 years after the program is installed upstream. Silting of roads and sedimentation of reservoirs will be reduced by control of erosion on land that contributes this material. Control of stream-bank erosion will reduce stream turbidity and stop bank cutting. Such reductions will affect indirect as well as direct damages.

Benefits from reduction of average annual damage to fish were estimated to be 50 percent of the total. Reduction of damages to wildlife was estimated to be 25 percent of total wildlife damages. The reason for the difference in percentage of damage reductions between fish and wildlife is that fish are benefited by the reduction of all floods, whereas wildlife is benefited by reduction of only the larger floods. Because of the many intangibles entering into the evaluation of fish and wildlife benefits these indicated benefits were not included in summary of flood reduction benefits in table 22.

Proposed stream channel improvement measures by reducing flood frequency accrue a small portion of the benefits included in reduction of flood waters. It is estimated that approximately $45,000 of the flood reduction benefits shown in table 22 will be derived from installation of this measure. In addition, the reduction in flood frequency following channel improvement will permit a higher use of approximately 42,675 acres of flood plain land. This land, now idle or used for pasture or forest production, will be suitable for annual crops and its value appreciably enhanced. It is estimated that land presently valued at $40.00 to $45.00 per acre will increase to $120 to $125 per acre, resulting in a total enhancement of $3,555,000. This sum will return an annual benefit of $142,200 at 4 percent.

CONSERVATION BENEFITS

The economic benefits to landowners from the installation of the recommended program were calculated separately for woodland and open land. Combined, the estimated average annual benefits are $18,993,740.

Woodland

In calculating benefits for forest land (including farm woodlands) data on areas and timber drain were obtained from three sources: (1) U. S. Agricultural Census, (2) recent U. S. Forest Service surveys, and (3) recent State forest service surveys of Connecticut forests.

In brief, benefits were determined by calculating the difference in values between yield without a program and yield with a program. A much larger yield in both quantity and quality of forest products will result from installation of the recommended program.

Present yield was determined by converting the 1944 harvest of all forest products to equivalent board feet in order to include yield from pole timber as well as saw timber stands. In this way the present annual yield of forest products was figured at 75 board feet per acre. An analysis of growth and drain data collected by the Forest Survey in New England indicated that growth and drain were approximately equal in the watershed and that products drain could logically be substituted for growth.

The long-term future annual yield of forest products without the recommended program installed was assumed to be equal to that at the present time. Yields on a comparable basis, but with a program, were based on an average of 280 board feet per acre per year. This future yield was determined from study of growth records of forest stands within the watershed and of comparable stands on areas outside the watershed. According to calculations of potential yields, the quantity yield with the program would be about 3.7 times that without the program. The quality of the products as a result of the program should also be very much better.

Prices for timber on the stump (stumpage) are conservatively estimated at an averate of $6 per thousand board feet

(or its equivalent) without the program and $10 with the program. The higher of the two reflects better-quality timber, better market outlets, and better utilization and marketing practices, on account of the program. Better quality of timber as a result of improved forest management has already been mentioned. Better market outlets and utilization and marketing practices will result from the forest utilization service that is part of the proposed program. The benefits from the installation of the recommended flood-control program in woodland areas are shown in table 23.

Table 23.--Estimated conservation benefits from woodlands with recommended program

Item	Production per acre	Value per acre	Woodland area	Value
	Board feet	Dollars	Acres	Dollars
With program	280	2.80	4,985,000	13,958,000
Without program[1]	280	2.80	625,000	1,750,000
	75	0.45	4,162,000	1,872,900
	--	--	--	3,622,900
Total benefit	--	--	--	10,335,100

1/ Present woodland programs affect 625,000 acres and are given full benefit for increased production.

Open Land

Conservation benefits on open land are derived from three interrelated sources: (1) savings in crop production costs, (2) decrease in present rate of soil loss, and (3) increase in crop and pasture yield. None of these sources is fully effective, however, without the installation of a complete program. In order to determine the value of the conservation benefits accruing to the recommended program,

it was necessary to compute the benefit of the complete program and then determine the percentage of total benefits accruing to the recommended program.

<u>Savings in production costs</u>.--Reductions in acreage of row crops and hay have been recommended for certain areas in the watershed. These conversions of cropland to less intensive use have been based on land-use capability. In such areas improper land use is causing excess runoff and accelerated erosion.

The amount of this reduction in acreage is shown for specific crops in table 24. Savings in cost of production, based on 1949 agricultural costs and prices, give an estimated annual benefit of $1,367,266.

Current programs will accomplish approximately 33 percent of the total need land conversions during the installation period. On this basis 67 percent of the total benefit or $916,068 will accrue to the recommended program.

It should be recognized that the savings in crop production cost shown in table 24 do not represent a complete picture of farm production costs. Additional operating costs of nearly $2,400,000 are included in the program costs. Therefore, it is necessary to include as a benefit the savings in production cost on those areas which will be converted to a less expensive form of use.

Table 24.--<u>Decrease in crop production costs due to land-use conversion</u> 1/

Crop	Present acreage	Proposed acreage	Net change in acreage	Savings in production cost per acre	Total reduction in cost
Silage corn	42,958	40,551	-2,047	$ 30	$ 61,410
Potatoes	19,379	18,391	- 988	147	145,236
Tobacco	12,444	10,578	-1,806	350	632,100
Vegetables	6,409	6,207	- 202	300	60,600
Hay 2/	762,771	739,375	-23,396	20	467,920
Total	--	--	--	--	$1,367,266

1/ Based on decreases in labor and other production costs resulting from land conversion.

2/ Includes permanent and rotation hay.

Decrease in rate of soil erosion.--Benefits to landowners from reductions in soil erosion rates were calculated on the assumption that as erosion occurs, all other production factors remaining the same, crop yields will decline. It is obvious that in many areas, under moderate erosion conditions, yields may not decline; however, this may be due to changes in improved production methods, such as increased fertilizer applications, new seeds and insecticides, longer crop rotations, and better cultural practices. Based on erosion and yield studies it is concluded that, in the absence of erosion, the adoption of the above improvements would result in still higher yields. It is apparent that the benefit from a reduction in soil erosion may occur through maintaining yields, lowering production costs, or maximizing the yield increases from possible improvement in production methods.

The computation of the effect of erosion on yields is shown in table 25. The rates of soil loss and corresponding decline in yields were based on studies of the Soil Conservation Service. The value of the annual yield decline, shown in this table, is $178,228. This value represents a cumulative loss increasing annually by the same amount. Its annual equivalent value, based on 50 years' duration, is $2,727,929. It is estimated that the total land treatment program will reduce the erosion rate by 75 percent, thus producing an annual benefit of $2,045,947.

Approximately 98 percent of this benefit will accrue from the conservation measures applied on cropland (table 25). It is estimated that current programs will accomplish 15 percent of the needed cropland measures and about 83 percent of the needed pasture measures and will accrue benefits accordingly. The remaining benefits ($1,711,229) will accrue to the recommended program.

It was considered that as erosion continues and crop yields decline, a point would be reached when it would no longer be profitable to farm the land in its present use. This would have a tendency to reduce the erosion damages as computed. Therefore, the annual equivalent value of the benefit was calculated for a 50-year period.

Increased yields due to water conservation and pasture-treatment measures.--Increased yields due to the water-conservation effects of the program measures were computed for all crops and pasture by the physiographic divisions of the watershed. The amounts of increase have been based on experiment station data. The monetary value of this effect of the program

Table 25.--Effect of erosion on value of crop and pasture production without land treatment program, Connecticut River watershed

Item	Value of present production	Annual soil loss	Yield decline per inch of soil loss	Annual yield decline	Value of annual yield decline
	(dollars)	(inches)	(percent)	(percent)	(dollars)
Upland (Conn. & Mass.)					
Silage corn	702,379	.0172	9.6	.1651	1,160
Potatoes	506,277	.0172	9.6	.1651	836
Vegetables	339,227	.0172	9.6	.1651	560
Hay	3,881,895	.0172	9.8	.1685	6,540
Pasture	262,593	.0077	9.6	.0739	194
Subtotal	5,692,371				9,290
Valley (Conn. & Mass.)					
Silage corn	2,433,041	.0500	8.0	.4000	9,732
Tobacco	9,094,075	.0500	7.6	.3800	34,557
Potatoes	5,254,938	.0500	8.0	.4000	21,020
Vegetables	2,476,940	.0500	8.0	.4000	9,908
Hay	6,772,118	.0500	9.8	.4900	33,183
Pasture	917,570	.0037	9.6	.0355	325
Subtotal	26,948,682				108,725
Upland (N.H. & Vt.)					
Silage Corn	1,317,232	.0408	6.3	.2570	3,385
Hay	14,250,920	.0408	9.5	.3876	55,236
Pasture	1,276,290	.0130	9.6	.1248	1,592
Subtotal	16,844,442				60,213
Totals	49,485,495				178,228

Table 26.--Estimated present value of agricultural production on acreage affected by watershed-improvement program

WITHOUT A PROGRAM

Crop	Acres	Yield per acre		Value per unit[1]	Value per acre	Value of production
	Number	Unit		Dollars	Dollars	Dollars
Silage corn						
Upland Conn. & Mass.	8,105	Ton	7.0	12.38	86.66	702,379
Upland N.H. & Vt.	15,200	Ton	7.0	12.38	86.66	1,317,232
Valley	19,653	Ton	10.0	12.38	123.80	2,433,041
	42,958	--	--	--	--	4,452,652
Potatoes						
Upland Conn. & Mass.	2,206	Bu.	150.0	1.53	229.50	506,277
Valley	17,173	Bu.	200.0	1.53	306.00	5,254,938
	19,379	--	--	--	--	5,761,215
Vegetables						
Upland Conn. & Mass.	989	--	--	--	343.00	339,227
Valley	5,420	--	--	--	457.00	2,476,940
	6,409	--	--	--	--	2,816,167
Tobacco	12,444	Lb.	1,575	.464	730.80	9,094,075
Hay						
Upland Conn. & Mass.	94,519	Ton	1.34	30.65	41.07	3,881,895
Upland N.H. & Vt.	346,991	Ton	1.34	30.65	41.07	14,250,920
Valley	122,750	Ton	1.80	30.65	55.17	6,772,118
	564,260	--	--	--	--	24,904,933
Pasture						
Upland Conn. & Mass.	29,177		--	--	9.00	262,593
Upland N. H. & Vt.	141,810		--	--	9.00	1,276,290
Valley	61,192		--	--	15.00	917,570
	232,179		--	--	--	2,456,453
Total value present condition						49,485,495

1/ 1949 prices, U. S. Dept. Agr. Bur. Agr. Econ.

Table 27.--Estimated future value of agricultural production on acreage affected by watershed-improvement program

WITH THE RECOMMENDED PROGRAM

Crop	Acres	Yield per acre		Value per unit 1/	Value per acre	Value of production
	Number	Unit		Dollars	Dollars	Dollars
Silage corn						
Upland Conn. & Mass.	7,654	Ton	7.7	12.38	93.33	714,348
Upland N.H. & Vt.	15,200	Ton	7.7	12.38	93.33	1,418,616
Valley	17,697	Ton	11.0	12.38	136.18	2,409,977
	40,551	--	--	--	--	4,542,941
Potatoes						
Upland Conn. & Mass.	2,148	Bu.	165	1.53	252.45	542,263
Valley	16,243	Bu.	220	1.53	336.60	5,467,394
	18,391	--	--	--	--	6,009,657
Vegetables						
Upland Conn. & Mass.	978	--	--	--	377.00	368,706
Valley	5,229	--	--	--	503.00	2,630,187
	6,207	--	--	--	--	2,998,893
Tobacco	10,578	Lb.	1,732	.464	803.64	8,500,904
Hay						
Upland Conn. & Mass.	87,812	Ton	1.64	30.65	50.27	4,414,309
Upland N.H. & Vt.	319,854	Ton	1.64	30.65	50.27	16,079,061
Valley	166,566	Ton	2.20	30.65	67.43	11,231,545
	574,232	--	--	--	--	31,724,915
Pasture (to be improved)						
Upland Conn. & Mass.	31,463	--	--	--	16.00	503,048
Upland N.H. & Vt.	55,513	--	--	--	16.00	888,208
Valley	36,869	--	--	--	27.00	995,463
	123,845	--	--	--	--	2,386,719
Pasture (to be managed)						
Upland Conn. & Mass.	20,570	--	--	--	9.90	203,643
Upland N.H. & Vt.	100,720	--	--	--	9.90	992,673
Valley	36,992	--	--	--	16.50	610,368
	158,282	--	--	--	--	1,806,684
		Total value with program				57,970,713
		Benefit				8,485,218

1/ 1949 prices, U. S. Dept. Agr. Bur. Agr. Econ.

is shown in tables 26 and 27 where present production and production with the control program have been estimated in terms of 1949 agricultural prices.

Pasture-treatment measures recommended to provide an adequate grass cover for control of surface runoff will also provide one-site benefits as shown in tables 26 and 27.

The total benefit from increased crop yields and increases in pasture production attributable to the watershed-improvement program amounts to $8,485,000 annually. Of this amount approximately $6,748,318 will accrue from increased crop yield and $1,736,900 from increased pasture yield. It is estimated that current programs will accomplish 15 percent of the needed cropland measures and 83 percent of the needed pasture treatment and will accrue benefits accordingly. The remaining benefits ($6,031,343) will accrue to the recommended program.

Summary of open land conservation benefits from recommended program.--The annual conservation benefits to open land from the three sources evaluated are (1) savings in crop production costs, $916,068, (2) decreased erosion, $1,711,229, and (3) increased yields, $6,031,343. The total open land conservation benefit accruing to the recommended program is $8,658,640.

COMPARISON OF BENEFITS AND COSTS

The ratio of total benefits of the program to total costs was calculated to determine the justification for the program on a monetary basis.

As a basis for comparison, total costs and total benefits were reduced to average annual values as follows:

1. Total average annual installation cost was determined by applying 2.5 percent (annual interest rate) to the total public installation cost, and 4 percent to the private installation cost. The resultant figure added to the annual maintenance cost after installation gives the average annual cost of installing, maintaining, and operating the recommended program (table 28).

2. Average annual benefits from the reduction of flood and sediment damages were added to the conservation benefits accruing to landowners and operators to provide the average annual benefits from the recommended program.

Table 28.--Comparison of estimated benefits and costs of recommended flood-control program

Item	Public cost	Private cost	Total
Installation cost	$24,919,000	$10,617,000	$35,536,000
Average annual installation cost 1/	623,000	425,000	1,048,000
Average annual maintenance cost	841,000	1,885,000	2,726,000
Total average annual cost	1,464,000	2,310,000	3,774,000
Average annual benefits	2/ $ 1,166,455	3/ $18,993,740	$20,160,195

1/ 2.5 percent of public installation costs, 4 percent of private installation costs.

2/ Benefits from reduction of floodwaters and sedimentation.

3/ Conservation benefits to landowners from increased production.

The following costs and benefits were discounted to present values to determine the benefit-cost ratio.

Timber-marking costs will be incurred gradually at an increasing rate of $19,000 per year for the first 20 years and at $9,500 per year for the next 40 years. Discounting public funds at 2½ percent and private funds at 4 percent reduced the average annual costs to $3,452,000.

Flood and sediment reduction benefits were assumed to be 45.5 percent available within 5 years after installation, 84.5 percent available in 30 years and 100 percent available in 70 years. These benefits are public and were discounted

at $2\frac{1}{2}$ percent. Future benefits of $1,024,255 were reduced to $759,168. Land enhancement values are available immediately on installation of channel-improvement measures and are not discounted.

Conservation benefits of $18,993,740 accrued to private individuals and were discounted at 4 percent. Benefits from reductions in cost and from increased crop and pasture production were assumed to be fully available in 5 years and were discounted accordingly.

Benefits from increased production of forest products were assumed to become available as follows:

75 percent in 30 years
100 percent in 70 years

Benefits from decreasing present rates of soil loss were assumed to increase in a straight line for 50 years.

Application of the discount factors reduced the estimated future annual conservation benefit to a present value of $12,254,357. Total benefits from floodwater reduction and conservation measures are $13,155,725.

The benefit ($13,155,725) ÷ cost ($3,452,000) ratio on the basis of present values is 3.8 : 1.

Additional Economic Appraisal

Because of expected changes from prevailing (1949) price relationships, some additional adjustments were made based on the price relationships anticipated in 1955-65, in a national economy functioning at an intermediate employment level. The indices used in making this adjustment were as follows:

Index	1949	1955-65	Change
Construction costs (Eng.News Rec.)	477	325	.681
Prices received by farmers (BAE)	249	150	.602
Prices paid by farmers (BAE)	238	155	.651
Wholesale lumber prices (BLS)	286	145	.506
Wholesale commodities (BLS)	155	106	.684

On this basis the average annual benefit becomes $7,500,853 and the average annual cost $2,295,000. The benefit-cost ratio is 3.2 : 1.

Table 29.--Benefit-cost comparison for stream-channel improvement program

Item	Public cost	Private cost	Total
Installation	$1,562,000	$240,000	$1,802,000
Interest rate	2.5 %	4.0 %	--
Average annual installation cost	39,050	9,600	48,650
Average annual maintenance cost	90,000	--	90,000
Total average annual cost	129,050	9,600	138,650
Adjustment indices	.683	.651	
Adjusted cost	88,141	6,250	94,391
Total average annual benefits 1/	--	--	187,200
Adjustment indices	--	--	.602
Adjusted benefit	--	--	112,694
Adusted benefit-cost ratio	--	--	1.20 : 1.00

1/ Benefits derived from enhancement of value of 42,675 acres of land removed from threat of recurrent floods. Total enhancement equals $3,555,000. Conversion to annual basis at 4 percent = $142,200. In addition, floodwater reduction benefit of approximately $45,000 will accrue from the establishment of this measure.

In addition to the over-all cost-benefit comparison required by law, present instructions call for an evaluation of cost and benefits in all measures, practices, and structures not directly associated with the land-treatment program. Improvement of stream channels is the only measure falling in this category and proposed in the recommended flood control program. The economic evaluation of this measure is given in table 29.

The recommended program described and evaluated in these appendixes includes forest land management measures for 4,985,000 acres, the area which should be treated to achieve the most effective program of runoff and water-flow retardation and soil-erosion prevention. An evaluation of the progress of the going program as it is now operating and as it is affected by the lack of some form of public control of forest practices on private land indicates that this full treatment will not be fully attained during the 20-year installation period.

In order to make the program consistent with these indications, the recommendations presented in the report include forest land measures for only the area on which it is estimated these measures will be installed and maintained. The quantities of forest land measures recommended in the report were obtained by estimating the percentage of accomplishments to be secured without some form of public control of forest practices on private forest land. These percentages, applied to the various practices included in the improved forest management measures for private forest land, reduced the area to be treated from 4,985,000 acres to 4,354,350 acres and reduced the installation cost from $22,437,000 to $18,372,000. The Federal Government will pay approximately $9,531,000 of the reduced cost, other public agencies $4,054,000, and private individuals $4,787,000. The annual operation and maintenance cost will be reduced from $1,311,000 to $823,000. Of the latter amount the Federal Government will pay about $246,000, other public agencies $222,000 and private individuals about $355,000.

Tree planting was also revised and is now recommended on 124,700 acres at an estimated installation cost of $1,503,000 to the Federal Government, $762,000 to other public agencies, and $716,000 to private individuals.

These changes resulted in a reduction of 31.1 percent in the average annual cost of the forest land program. This percentage reduction was applied to the benefits derived from the total forest land program and resulted in the following changes:

1. Reduction in flood and sediment damages shown on page 73 was reduced from $1,166,455 to $896,000.

2. Total woodland production benefits, shown on page 77, were reduced from $10,355,000 to $7,121,000.

The net effect on the (1949) annual costs and benefits of the land treatment measures, as shown on pages 84 and 85, was a change in costs from $3,452,000 to $2,892,800, and a change in benefits from $13,155,725 to $10,808,000. Costs and benefits based on 1955-1965 prices changed respectively from $2,295,000 to $1,923,420 and $7,500,853 to $6,162,000, making a benefit-cost ratio of 3.2 to 1.

STATE OF VERMONT
Development Commission
Montpelier

July 6, 1950

Mr. Arthur Bevan
Chief of Flood Control Surveys
Northeastern Forest Experiment Station
102 Motors Avenue
Upper Darby, Pa.

Dear Mr. Bevan:

I want to take this opportunity to thank you for being present at the meeting of the Resources and Land Use Advisory Committee to the Vermont Development Commission on June 12th. We all enjoyed your presentation of the report on the Connecticut River Flood Control Survey and I know that it cleared up a great many questions that the members of the committee had regarding it.

For your information I am enclosing a copy of the minutes of the meeting.

Cordially,

/s/ Lester W. Eaton

Lester W. Eaton, Secretary
Resources and Land Use Advisory Committee

LWE:mp
Encl.

THE COMMONWEALTH OF MASSACHUSETTS

STATE PLANNING BOARD

11 Beacon Street
Boston 8

April 10, 1950

Mr. V. L. Harper, Director
United States Department of Agriculture
Forest Service
102 Motor Ave., Upper Darby, Pa.

Dear Mr. Harper:-

Reference is made to recent telephone conversations with Mr. G.L. Varney of your office concerning the Flood Control Survey Report for the Connecticut River Watershed, and to the letter from your office under date of February 28, 1950, signed by Arthur Bevan, Acting Director, in which he states that you would like a letter from this Board "stating that the tentative draft of the report has been reviewed and that in general the recommended program measures and practices offer a satisfactory method of controlling runoff and preventing soil erosion through installation of improved land management practices in the area of the watershed within the State."

I am now directed to advise you in reply that while the State Planning Board appreciates very much the opportunity given them to examine this report and, while it is very much interested in your long-range program for the preservation and improvement of our forests, it believes that definite provision should be made for its coordination with a flood control program, already approved, and designed to afford immediate protection from flood losses.

Without going toomuch into detail, I might add that the Board is concerned at the failure of the report to give more specific information as to the areas proposed to be converted from open land to woodland and the areas proposed to be purchased by the State for forestry purposes. Without such detailed information, it is difficult to make any reasonable appraisal of the effect of the program on the economy of the State.

The members of the State Planning Board believe that the report is a sincere conscientious effort to develop a program of water-flow retardation in aid of flood control and that there is much contained in it worthy of commendation. It believes it to be fundamental, however, that your program should be coordinated with that of other agencies and that in the last analysis, the recommendations should be made with the understanding that before being carried into effect, they will meet with the approval of the interested authorities of this Commonwealth.

Sincerely yours,

/s/ Elis. M. Herlihy

(Miss) Elisabeth M. Herlihy
Chairman

EMH:C

STATE PARK AND FOREST COMMISSION

STATE OF CONNECTICUT

165 Capitol Avenue
Hartford

July 20, 1949

Arthur Bevan, Chief
Division of Flood Control Surveys
United States Department of Agriculture
102 Motors Avenue
Upper Darby, Pa.

Dear Mr. Bevan:

I am sorry that I failed to send you a copy of the resolution passed by the group at Hartford last month.

Herewith is an extract from the minutes of our meeting:

RESOLVED: That this meeting unqualifiedly endorse the principle of this plan and earnestly commend it to the favorable consideration of Massachusetts, New Hampshire and Vermont.

Thanks for the information about the other New England States and I trust that you will keep us posted as to further progress.

Yours very truly,

/s/ D. C. Mathews

Donald C. Mathews
Director

DCM
MEH

STATE OF NEW HAMPSHIRE
Forestry and Recreation Commission
Concord

June 22, 1949

The Secretary of Agriculture,
Washington, D. C.

Dear Sir:

"The Tentative Report of the Flood Control Survey of the Connecticut River Watershed" prepared by the U. S. Forest Service in cooperation with the Soil Conservation Service has been examined and discussed in detail with representatives of the above agencies at a meeting in Concord, N.H., on June 20, 1949.

The measures recommended in this report appear to us to be eminently sound and based on reliable, factual studies. The program is reasonable in relation to the benefits to accrue both to the site occupants and those downstream; it proposes permanent correction of factors responsible for floods, erosion and siltation. These measures will supplement, and protect, but in no way interfere with other programs and structures designed for emergency control of floods.

The implementation of this program involves no new agency; but can be accomplished by existing Soil Conservation Districts, County Foresters under the Norris Doxey Act and other state and federal agencies with the additional financial support set forth in the report.

We therefore wish to record our endorsement of the recommendations in this report, and extend our offer of whole-hearted cooperation in carrying out these objectives.

/s/ George M. Putnam, Pres FARM BUREAU FEDERATION	/s/ John H. Foster STATE FORESTER
/s/ K. E. Barraclough EXTENSION FORESTER	/s/ Hilbert R. Siegler, Biologist for DIRECTOR, FISH AND GAME DEPARTMENT
/s/ Harry K. Roznic FORESTRY AND RECREATION COMMISSION	/s/ Leonard R. Frost WATER RESOURCES BOARD, Engineer
/s/ Perley I. Fitts COMMISSIONER OF AGRICULTURE	/s/ Edward Ellingwood PLANNING & DEVELOPMENT COMMISSION

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

In reply refer to:
River Basin Studies
Conn.R.-Forest Ser.
Boston Division

Office of Regional Director
Blake Building
Boston 11, Massachusetts

June 13, 1949

Mr. V. L. Harper, Director
Northeast Forest Experimentation Station
United States Forest Service
102 Motors Avenue
Upper Darby, Pennsylvania

Dear Sir:

Further reference is made to your letter dated April 26, 1949, and to your report entitled "Tentative Report on Flood Control Survey of the Connecticut River Watershed."

The subject report has been reviewed with considerable interest. Such a comprehensive land program as is outlined would certainly be worthwhile to the Connecticut Valley.

There are no proposals in the plan that fall within the purview of this Service. Should it develop that we can be of assistance in any phase of your action program, we would be pleased to have your contact us.

Very truly yours,

/s/ E. W. Bailey

E. W. Bailey
Acting Regional Director

DEPARTMENT OF COMMERCE
U.S. COAST AND GEODETIC SURVEY
WASHINGTON 25

In reply address the Director
U.S.Coast & Geodetic Survey and
not the signer of thie letter

And Refer to No. 60-mlh

3 May 1949

The Director
Northeastern Forest Service Station
Department of Agriculture
102 Motors Avenue
Upper Darby, Pennsylvania

Dear Sir:

Your letter of 26 April 1949 to the Supervisor, Eastern District, U. S. Coast and Geodetic Survey, 90 Church Street, New York, N. Y., file RIFC-NE Connecticut Survey Report, has been forwarded to this office.

This Bureau maintains a general interest in all conservation programs affecting the natural resources of our country. Specifically, our interest in the Connecticut River project is confined to those details connected with geodetic surveys. It is our desire to cooperate to the fullest extent with such available geodetic control data as may be needed for the successful completion of the project.

These data are useful in coordinating individual surveys in connection with your program of more effective land utilization. Under separate post, I am sending you state maps on which are indicated the location of triangulation stations for which geographic positions are available, and also maps showing bench marks for which elevations above sea-level are determined. I shall be glad to send you any such data you may desire providing you will specify the localities in which you are interested.

I am also sending you Special Publication No. 226, "Horizontal Control Data" and Special Publication No. 227, "Control Leveling", which describe our geodetic surveys and indicate their general usefulness, particularly for large scale engineering development projects.

Very truly yours,

/s/ J. H. Hawley

Acting Director

CC: Supervisor, Eastern District

UNITED STATES DEPARTMENT OF COMMERCE
Weather Bureau

In reply refer to
File 070.1
HYD/hk

May 25, 1949

In reply address
Regional Director
Weather Bureau Regional Office
383 Madison Avenue
New York 17, N. Y.

Director
Northeastern Forest Experiment Station
102 Motors Avenue
Upper Darby, Pa.

Dear Sir:

Your Tentative Report on Flood Control Survey of the Connecticut River Watershed was studied at this office, with the view of possible cooperation in the proposed installations of hydrologic stations. At the present time, the Weather Bureau maintains in the Connecticut River Watershed some 90 precipitation gages, 25% of which are of recording type. While this density of precipitation network (approximately one gage to every 125 square miles) is quite adequate for Weather Bureau purposes, it is realized that it may not be sufficient for your project, which calls for the establishment of a number of small index areas in the watershed, each equipped with a dense network of hydrologic stations. Ordinarily, installations of such "project networks" are of limited interest to the Weather Bureau, and cooperation with other agencies in this matter falls in the jurisdiction of the Washington Central Office and possibly for consideration of Federal Inter-agency River Basin Committee.

It is suggested that when your plans materialize, and if you so desire, a formal proposal to the Chief, U. S. Weather Bureau, be made by you in regard to the cooperation in the installation and maintenance of hydrologic stations in your project areas, accompanied by proposal for fianacial arrangements.

It is also suggested that advantage be taken by you of existing hydrologic stations in the Connecticut Watershed. These stations are indicated on the FIRBC Map No. 2.

Very truly yours,

/s/ W. J. Moxom

W. J. Moxom
Regional Director

cc: CO, Wash., D.C., C&HS Div.

U. S. DEPARTMENT OF COMMERCE
BUREAU OF FOREIGN AND DOMESTIC COMMERCE
Field Service

Boston Regional Office:

1800 Customhouse
2 India Street
Boston 9, Mass.

May 12, 1949

Mr. V. L. Harper
Director
U. S. Dept of Agriculture
102 Motors Avenue
Upper Darby, Pennsylvania

Dear Mr. Harper:

Referring to your letter of April 26th, RIFC-NE Connecticut Survey Report, please be advised that I have just returned to the office after an illness to find your letter together with the tentative report on flood control in the Connecticut River watershed.

I have not yet had an opportunity to go through the report, therefore I have no comments which I can offer. I can only say that this office is interested in the operation of water control, particularly for the reduction of flood damage.

Very truly yours,

/s/ Harold P. Smith

Harold P. Smith
Regional Director

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
Region One
Richmond, Virginig

May 10, 1949

Director,
Northeastern Forest Experiment Station,
102 Motors Avenue,
Upper Darby, Pennsylvania.

Dear Sir:

Acknowledgment is made of your letter of April 26 transmitting for our review and comments a copy of Tentative Report on Flood Control Survey of the Connecticut River Watershed (File No. RIFC-NE.)

The report has been reviewed with interest and appreciation by this office. It appears that none of the recommendations proposed will have deleterious effects upon areas administered by or proposed for administration by this Service.

Sincerely yours,

/s/ Elbert Cox

Elbert Cox,
Associate Regional Director.

FEDERAL POWER COMMISSION
Regional Office

1601 Park-Murray Bldg.
11 Park Place
New York 7, New York

May 24, 1949

Mr. H. L. Harper, Director
Northeastern Forest Experiment Station
102 Motors Avenue
Upper Darby, Pennsylvania

Dear Mr. Harper:

Pursuant to the request contained in your letter of April 26, 1949, we have reviewed the tentative report on flood control in the Connecticut River watershed, a copy of which was attached to your letter, and are giving you in the following our comments thereon.

It is understood that this report has been prepared under provisions of the Flood Control Act of June 22, 1936, Public Law No. 738, 74th Congress and in compliance with the Flood Control Act of 1944, Public Law No. 534, 78th Congress, Second Session, authorizing preliminary examinations and surveys for runoff and waterflow retardation and soil erosion prevention on the watershed of the Connecticut River in Massachusetts, New Hampshire, Vermont, and Connecticut. In the report under review recommendations are made for carrying out these objectives, together with an analysis of the costs and benefits thereof.

It is noted that the total cost of the recommended program, to be carried out over a 20-year period, is estimated at $53,156,000, of which $25,557,000 would be borne by public agencies and $27,599,000 by private interests. The total annual benefits are estimated to be $22,273,000, of which $1,757,000 is credited to flood control, and the total annual cost of the improvements at $3,451,000,resulting in a benefit-cost ration of 6.45 to 1.0.

The recommended program of improved land use and management, consisting of interdependent measures, practices, and minor structures for runoff and waterflow retardation and soil erosion prevention, includes the following items as listed in the report:

1. Conversion of about 226,800 acres of open land to woodland, including the planting of about 150,000 acres, or two-thirds of this area.

2. Public acquisition of approximately 154,000 acres of land in critical flood and silt source areas.

3. Initiation of improved management practices on 4,985,000 acres of woodland, details of which are further outlined in the report.

4. Construction of 2,000,000 rods of fence to exclude livestock from woodlands.

5. Investigation of mountain torrent action, and development and installation of measures and structures to control water and debris movement in headwater channels and reduce stream-bank damage throughout the watershed.

6. Installation of hydrologic stations for testing the effectiveness of interdependent measures and adjusting action programs.

7. Construction of approximately 990 miles of diversions and 950 miles of terraces to intercept and divert surface runoff and reduce sediment production.

8. Installation of approximately 690 miles of waterways by shaping and establishing vegetation to provide suitable outlets for the disposal of concentrated runoff from fields and small subwatersheds.

9. Construction of approximately 2,900 erosion and sediment-control structures in waterways.

10. Construction of approximately 17,400 miles of contour furrows on about 43,700 acres of pasture.

11. Establishment of approximately 65,900 acres of perennial hay and 63,000 acres of new pasture; improvement of approximately 31,600 accitional acres of pasture by seeding, liming, and fertilizing.

12. Initiation of other soil and water conservation practices, such as strip cropping, contour cultivation, crop rotations, cover crops, crop residue management, pasture management, and related measures.

13. Provision of technical assistance for planning and applying the necessary land-use adjustments for planning and applying the recommended conservation practices on open land and woodland, and for integrating the measures included in the recommended program.

SUMMARY AND CONCLUSIONS

The New York Regional Office of the Federal Power Commission has reviewed the tentative Flood Control Report on the Connecticut River, prepared by the Northeastern Forest Experiment Station of the U. S. Department of Agriculture, and has the following comments to make thereon.

It is understood that the purpose of the recommended program, as outlined in the report, is to reduce flood damages in the Connecticut River watershed by increasing the infiltration rate and water-holding capacity of the soil, thus reducing the rapid discharge of flood waters and soil erosion. In its broader aspects, the program includes changes in land use and improvements in management measures, all for the purpose of building up and maintaining cover and soil conditions that are favorable to watershed protection.

It is also understood that, in addition to soil measures, consideration was given to engineering works, such as reservoirs, dykes and other structures, but no details of any of them are given in the report. It is conceivable that some of the proposed flood retarding dams will control sizable drainage areas, in which case the raising of the structures might yield sufficient conservation storage to make the development of small amounts of hydroelectric power for local or rural consumption economically feasible. It appears, therefore, that this phase of the proposed program might deserve further consideration and, if so, we shall be glad to cooperate with your office in the investigation of the power potentialities of such projects.

In the Appendix of the report, pages 107 to 130, inclusive, an analysis is made to determine the reduction in flood runoff in a sample watershed on the Farmington River if the recommended land-use changes had been in operation during the serious floods of 1927, 1936, and 1938. However, no quantitative analysis was made to determine the

increase in low water flows due to the recommended improvements, due in particular to the increase in the infiltration rate and water-holding capacity of the soil, and no credit was taken for the resulting benefits accruing to existing and proposed hydroelectric developments on the river during the low flow period of each year. It is believed that this phase of the improvement should be given appropriate recognition in the final draft of the report.

We have no further comments to make at this time with respect to the contents of the tentative report on the Connecticut River and its tributaries but it is assumed that, in accordance with procedures adopted under the Federal Interagency Agreement, this office will be given an opportunity to review the final draft of the report before its submission to higher authority .

Very truly yours,

/s/ D. J. Wait

D. J. Wait
Regional Engineer

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
Office of the Division Engineer
New England Division

Refer to File No. NEDGW

July 25, 1949

Director, Northeastern Forest Experiment Station
U. S. Department of Agriculture
102 Motors Avenue
Upper Darby, Pennsylvania

Dear Sir:

Reference is made to your letter dated April 26, 1949, your file RIFC-NE CONNECTICUT SURVEY REPORT, requesting comments by this office on your "Tentative Report on Flood Control Survey of the Connecticut River Watershed", which was the subject of the conference held with representatives of your office on June 28. Several aspects of the report were clarified at the conference. The principal points still in question are outlined below:

1. Concerning the hydrology presented in the report, the following observations are made:

a. All flood hydrographs are analysed in terms of volume instead of discharge rates which is believed to be preferable. Also, the questionable assumption is made that a volume reduction is directly applicable to the discharge peak.

b. The report contains no studies of river hydraulics, such as routing, concurrent timing of peak flows, and actual contributions of tributary flows to the main river flood which are considered essential in the determination of flood reductions.

c. In the analysis of the Farmington River no credit has been given to the large volume of runoff stored in reservoirs throughout the basin. According to the U. S. Geological Survey the surface run-off in the hurricane flood of September 1938 amounted to 5.2 inches whereas the report assumes only 3.8 inches with the difference credited entirely to infiltration rates and sub-surface storage.

d. Infiltration rates given in the report appear high and raise the question of the reliability of applying infiltrometer readings for a small selected area to a large river basin.

2. It is realized that the hydrology of soils is a new and complex field allowing considerable difference of opinion on the effect of changes in land use on stream flow. It is believed that the analysis

used in the report and the assumptions made therein should be applied to reproduce a number of actual observed flood hydrographs in order to check on the accuracy of the method and assumptions made before the analysis is accepted.

3. The report appears to over-emphasize flood control especially when it is noted that the on-site benefits, attributable to a land management program, are over ten times the off-site or downstream benefits, attributable to reduction in flood damages by reason of increased infiltration rates. Moreover, the Flood Control Acts of 1936 and 1938 direct that "Federal investigations of watersheds and measures for runoff and water flow retardation and soil erosion prevention" be prosecuted by the Department of Agriculture, in contrast to directing investigations for flood control and allied purposes by the Chief of Engineers. It is suggested, therefore, that the secondary title be adopted as the principal title: "Report on a Program for Runoff and Water Flow Retardation and Soil Erosion Prevention for the Connecticut River Watershed".

4. The report should contain a clear statement as to how the proposed program of the U.S.D.A. will be coordinated with other related programs authorized by the Congress, such as the approved program of flood control reservoirs and local works to be constructed by the Corps of Engineers. An informative brief concerning the Corps of Engineers' program, suitable for inclusion in the report, is inclosed herewith.

FOR THE DIVISION ENGINEER:

Very truly yours

/s/ F. W. Salfingere

F. W. SALFINGERE
Major, Corps of Engineers
Executive Officer

Incl.
Brief

COOPERATIVE EXTENSION WORK
in
Agriculture and Home Economics
State of Vermont

August 22, 1950

Mr. V. L. Harper, Director
Northeastern Forest Experiment Station
U.S.D.A.
102 Motors Avenue
Upper Darby, Pa.

Dear Mr. Harper:

Re: Connecticut Watershed Survey Report

Your letter to Dr. J. E. Carrigan relative to the final draft of the flood control report of the Connecticut River Watershed has come to me for answer. As you know Director Carrigan has been away in Ireland for the past two years and I have been handling this phase of the work and have met several times with various people in connection with this survey report.

I have read through the final draft and as far as I can see it is satisfactory for submission to the secreatry's office.

Very truly yours,

/s/ R. P. Davison

R. P. Davison
County Agent Leader

RPD:mcl

UNITED STATES DEPARTMENT OF AGRICULTURE
Production and Marketing Administration
University of Massachusetts
Amherst, Massachusetts

September 5, 1950

Mr. V. L. Harper
U. S. Department of Agriculture
Forest Service
102 Motors Avenue
Upper Darby, Pennsylvania

Dear Mr. Harper:

The Survey Report of the Connecticut River Watershed that you submitted to me for consideration is hereby approved.

Your are to be congratulated on finally completing this rather exhaustive study and including in it so much valuable reference to the agriculture of the region.

I was interested in following through the soil building practices that still needed to be accomplished to achieve the most soil and water conservation for the area.

Very truly yours,

/s/ Harold F. Tompson

Harold F. Tompson, Chairman
Mass. State PMA Committee

UNITED STATES DEPARTMENT OF AGRICULTURE
Production and Marketing Administration
29 Mine Street, Durham, New Hampshire

August 29, 1950

Mr. C. R. Lockard, Acting Director
RIFC-NE Connecticut Watershed
102 Motors Avenue
Upper Darby, Pennsylvania

Subject: Survey Report

Dear Mr. Lockard:

I have studied the reports of the survey of the Connecticut River Watershed, and I believe it is of vital importance that something of this nature be attempted as soon as possible. We all know of the terrific damage to property every time a flood occurs, without taking into account the possible loss of life that goes with a major catastrophe of that nature.

There is one comment that I would like to make before any work starts on the project. From our point of view as farmers, we sometimes wonder if the location of the dams is always for the best interests of the farming people. In other words it seems too bad that the location is often such that acres of the best land is taken out of cultivation, when it really seems that if located at a different place, the same results could be obtained and still allow use of this better type of soil for farming.

Reforesting hundreds of acres is going to be one of the major necessities of this project in order to get the best result of retaining the water. This is going to call for an intense educational program of all property owners within the watershed, especially of the property on the higher levels. All of the Agricultural Agencies within the territory should work together and try to set this across.

If and when this project starts, our state and county office people will be very ready and willing to do everything possible to assist the proposition.

Yours very truly,

/s/ Harold E. Hardy

Harold E. Hardy, Acting Chairman
PMA State Committee

UNITED STATES DEPARTMENT OF AGRICULTURE
Production and Marketing Administration

500 Capitol Avenue
Hartford 6, Connecticut

August 21, 1950

Mr. V. L. Harper, Director
United States Department of Agriculture
Forest Service
N.E. Forest Experiment Station
102 Motors Avenue
Upper Darby, Pa.

Dear Mr. Harper   Attention: C. R. Lockard

Thank you for your letter of August 11 to which was attached the flood control report on the Connecticut River watershed.

Since I am going to be away from the office until after Labor Day, I will have no comments or statements on the report you are submitting to Washington. I have taken the "Survey Report" with me so that I may review it while on leave.

Very truly yours,

/s/ Walter T. Clark

Walter T. Clark
Executive Officer

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